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MAXIMUM PC

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BUILD THIS AMD MARVEL

- Starring AMD's new RX 7900 GRE
- 4K gaming for $2,800
- Benched against RTX 4070 Super





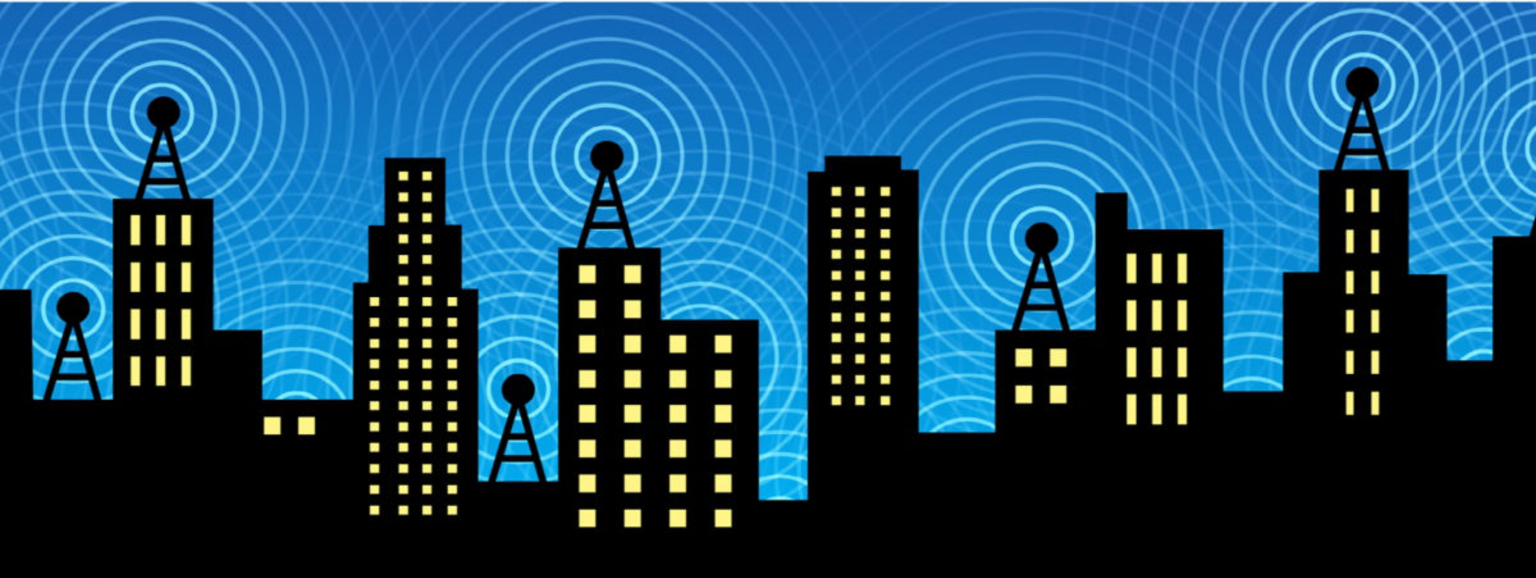
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inside

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Guy Cocker

FALLING DOWN THE RABBIT HOLE

JUST WHEN it felt like we were seeing the end of new graphics cards this year, AMD surprised us by importing its RX 7900 'Golden Rabbit Edition' from China for a worldwide audience. True, AMD's gaming business is struggling in the face of strong competition from Intel and particularly Nvidia (see news on page 9), but that hasn't stopped Team Red from releasing some stellar products, helping keep the market more competitive in the process.

The RX 7900 GRE, then, is the star of this month's cover build, as masterminded by our resident master builder, Zak Storey. We reviewed the card in our last issue, and gave it a score of 8, leading me to ask Zak to prioritize it for a build. The card sits in between AMD's RX 7800 XT and RX 7900 XT at what is now sadly the mid-range price point of $550. That's the same as an RTX 4070, and $50 lower than the newer RTX 4070 Super. As you'll read, those are comparisons that work out quite favorably for AMD's bunny-themed card, even against the more expensive Nvidia model. AMD is still behind when it comes to ray tracing and AI-based upscaling, but the raw performance is there. It makes things a lot more interesting if you have $550-600 to spend on a graphics card.

As I write this, Computex in Taiwan is just days away. Could Nvidia announce new consumer graphics cards? If they do, it'll undoubtedly be at the higher end, possibly either a 5080 or 5090—see page 10 for the latest speculation. As for Intel, they'll no doubt be falling over themselves to talk more about AI, but will they tell us more about the next generation of desktop CPUs? You'll be able to read all about it in these pages, whatever happens.

The other theme running through this issue is OLEDs. I saw lots of them out at the Consumer Electronics Show in January, but they're now here, storming the gates. We have the Alienware 4K model leading this month's reviews section, plus a 1440p screen from Acer. Next month, I'm hoping for another OLED from Philips. I've been effusive about OLED for gaming for a while now, along with our resident display specialist, Jeremy Laird, but will your next monitor be an OLED? Let me know by emailing me on editor@maximumpc.com.

In reviews, it's a real tale of beauty and the beast for our reviewer, Zak. He's found the best-value PCIe 4.0 SSD ever—good news for someone like me, who's still not convinced by the benefits of PCIe 5.0 at current prices. He's also taken a look at a foldable laptop that isn't quite ready for primetime. I've been a big fan of foldable phones, and had been looking forward to similar portable PCs, but it seems like we're not quite there yet. Turn to page 72 onwards to find out more.

A more efficient idea is probably to use a tablet as a second screen for your laptop, something you can do by reading our how-to on page 70. We also show you how to back up everything, stay private online, and choose the best web browser, all for free.

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's *editor-in-chief. He built his first gaming PC in 1997 to play* Tomb Raider *on 3dfx, and has been obsessed with all things PC ever since.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

Welcome to the AI PC

Microsoft unveils a new type of computer

IF AI IS BASICALLY MATH, then computers are obviously going to be good at it. The basic idea is nothing new, of course, what with a paper published in 1943 that outlined the first model of a neural network. Since then, we've been waiting on hardware that can really deliver on that notion. Well, AI is suddenly everywhere, all at once, and every technology company is falling over themselves to incorporate it into every process imaginable. Inevitably, that includes the PC. Microsoft's partnership with OpenAI is at the forefront of the AI industry, and with that comes not only a whole slew of new AI features for Windows, but a whole class of machines—there is now an official Microsoft AI PC.

Before we get too excited, there is nothing terribly revolutionary here. The AI PC is a set of hardware and software specifications—some utterly trivial, some a little trickier to achieve. All you need is an approved processor capable of 40 TOPS of AI processing (that's the tricky bit, more on which later), 16GB of DDR5 and 256GB of SSD storage. Oh, and you'll also need a Copilot key on the keyboard. Microsoft heralds the result as the "fastest, most intelligent Windows PCs ever built", a grandiose piece of flummery. Arguably, what is really being sold is the integration of AI into Windows. So far, the AI PC consists of Surface, Surface Pro laptops, and an army of new laptops from the usual suspects: Acer, ASUS, Dell, HP, Lenovo, and Samsung. Microsoft expects 50 million AI PCs to be sold over the next 12 months

If that's pretty predictable, there's a catch. All of those systems are powered by the Qualcomm Snapdragon X Elite processor, an Arm-based chip. There isn't an Intel or AMD x86 CPU in sight. This is also arguably the first truly serious attempt to get Windows running on Arm hardware. That TOPS metric, Trillions of Operations Per Second, is used to measure the performance of AI, specifically the hardware NPU. It's the NPU specifically that must deliver 45 TOPS to qualify for Microsoft's AI definition. That's why AMD's Phoenix APU and Intel's Meteor Lake laptop chips don't qualify, with their NPUs delivering 16 and 11 TOPS respectively. Nvidia's latest RTX 40 GPUs, including its mobile chips for laptops, all far exceed 45 TOPS, but simply do not qualify.



Microsoft reckons the Copilot key is the AI-powered answer to any question you may have.

For now, only laptops with the new Snapdragon X Elite SoC meet the standard, and it does rather seem like that was intentional. Later this year, AMD's new Strix Point APU and Intel's Lunar Lake chip will meet the standard. There have also been rumors about Nvidia and AMD getting into Arm-based PC processors. In a recent interview, Michael Dell was asked about an AI PC with Nvidia hardware. He said, "Come back next year" Jensen Huang, Nvidia's CEO, added, "Exactly". Nvidia certainly has most of the silicon it would need, the engineers, and funding, so Qualcomm's dominance is unlikely to survive for long.

However, the question remains whether the AI PC is all marketing fluff or something more substantial. In a lengthy blog post, Microsoft tries to explain that the initiative is about pushing the integration of AI, rather than trying to invent a new class of PC. Microsoft wants Copilot front and center whenever you use your Windows rig, and with much of the AI running locally. Every task will have AI help at hand: searching, image editing, writing, and more. With that omnipresent approach, however, come concerns. For instance, 'Recall' is a new Windows AI feature that tracks nearly everything you do, the sites you've visited, the images you've viewed, and so forth, taking snapshots as it goes. This creates a digital timeline you can explore and search. Can't find that picture of the cute cat you saw a few weeks ago? Recall takes you to it. Useful? Yes. Private? Not really. It has been dubbed a privacy nightmare by some, and prompted calls for regulation. The snapshots are stored locally and encrypted, but anybody with access to your system can view your activities for months, including financial, personal, embarrassing, and just plain private stuff. At least you can turn it off.

All of this makes Microsoft's AI PC initiative a curious thing. There are some useful features being touted underneath the marketing and hyperbole, but equally, pretty soon every new PC will have the qualifying hardware, and it's yet to be seen if there will be any truly compelling applications that run locally on those NPUs, as opposed to the cloud. In the meantime, the new Copilot+ PC starts at $999, and is available to order. **–CL**



> For now, only laptops with the new Snapdragon X Elite SoC meet the standard

AMD'S GAMING DIVISION STRUGGLING



THE FIGURES FOR AMD'S earnings for the first quarter of the year have arrived, and the gaming division doesn't make for happy reading. Numbers are down by 48 percent year on year. Sales, in both discrete graphic cards and custom GPUs, have tanked. Remember when we had trouble buying cards at all? No more. The market is flooded, and most of them are wearing green badges. Nvidia currently has about 80 percent of the discrete card market, while Intel has pinched a percentage or two in the bottom tiers. This doesn't leave much room for AMD. Nvidia is flush with cash and resources, so going head to head in premium GPUs is a reach. The rumor is that AMD will abandon the high-end graphic card market for its next-gen RDNA 4 GPUs, leaving Nvidia to play alone. It'll follow the money, meaning data centers, clouds, and AI. There is one weapon left in its arsenal, though: drop prices until you can sell everything you make. **–CL**

GOOGLE AI IN EVERYTHING



GOOGLE USES ITS annual I/O event to set out its plans, and this year the theme was simple: whatever the product, it was about how AI can improve it. Like it or lump it, you'll be interacting with Gemini, Google's brand for its LLM AI engine. There are dozens of interconnected AI initiatives covering images, Gmail, and even Workspace. The most obvious change is to Google search, which is shifting to being a "search generative experience", dubbed AI Overviews. This replaces hard links with an AI-generated summary. Depending on the query, it can return a completely AI-supplied reply. Not everybody is happy about this. The results are far from infallible, and cite precious few original sources. It isn't easy to disable, either. However, if you use the Web Search as the default, you can return to a simpler time. Google has been talking about AI for years, but in the last few months, actual application on a large scale has started. It's all going to get pretty interesting, pretty fast. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

NEW STANDARD FOR TRACKERS LAUNCHED
Dubbed DULT, it warns if a tracker is following you, so it's not used to stalk people.

TAPE ISN'T DEAD
Shipments are up three percent to 152.9 compressed exabytes—that's a billion gigabytes each.

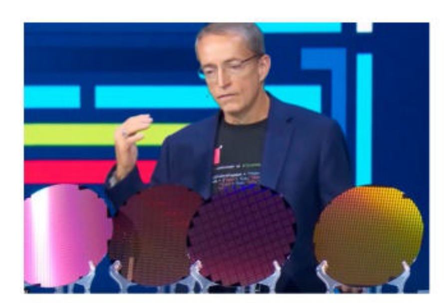
MIND READING
Researchers have turned brain activity into words, thanks to electrodes. Well, certain words at a 77 percent accuracy.

TRAGEDIES

SILENT RUNNING
The silence of an electric car isn't good for pedestrians: a study shows that twice as many people are hit by EVs over ICE.

AI'S POWER PROBLEM
By 2026, it's estimated that LLMs will burn through as much power as Japan.

GOOGLE'S SEARCH SNAFUS
Using AI to search has a few problems. Users have been told that staring into the sun is safe, and to eat a rock every day.



ARROW LAKE GETS 21 SKUS

Intel finally ready for a major desktop launch

THE ARRIVAL of Intel's Arrow Lake CPU is a big deal. We have a new socket, process, tile-based construction, features, core architecture in Lion Cove, AI hardware, and more. Intel plans to release 21 SKUs (Stock Keeping Units). It's the biggest launch since Alder Lake in 2021.

There's new branding, too—no more 'i', as Arrow Lake is to be the Core Ultra 200-series. The Ultra 100-series was the mobile Meteor Lake, a tile-based design that never made it to a desktop. Top dog is expected to be the Core Ultra 9 285K with 24 cores. That's eight performance and 16 efficiency cores, or '8P+16E' in Intel speak. It has a base clock of 3.6Ghz, and a maximum boost of 5.5GHz. Then there's Ultra 7 265K, with 8P+12E cores running at a base clock of 2.8GHz, and the Ultra 5 245K with 6P+8E cores, on the same clock.

These are 'leaks', not official specs. But with a launch expected later this year, the odds are high that these are accurate. Along with those are the usual mainstream 65W workhorses and 35W low-power models. Partnered with Arrow Lake will be a new mobile CPU: Lunar Lake. This sports a 4P+4E configuration, and will face competition from Snapdragon, Apple's new M3 chip, and AMD's finest.

Notably, Arrow Lake will debut the 20A process, while 18A is due for volume production next year. The catch is that only the CPU die within Arrow Lake will be made on Intel 20A silicon. Even then, it's rumored that most Arrow Lake SKUs will use a TSMC process for the CPU die. That would mean a pure TSMC chip, as the other tiles are already made by TSMC. As for Lunar Lake, that's pure TSMC. Even with the arrival of Arrow Lake and Lunar Lake, Intel will be nowhere near the technological driving seat in chip manufacturing. But depending on how good those Lion Cove cores are, it could still look decent when it comes to performance. **–CL**



APPLE'S NEW M4 CHIP ARRIVES

New SoC makes its debut in the iPad Pro

MERE months after the M3 first appeared, there's already a new Apple M chip—this time in an iPad, the first time new silicon hasn't debuted in a Mac. The SoC uses a 2nd gen 3nm process courtesy of TSMC, and is the first time Apple has given its M silicon CPU cores a major overhaul. Single-core performance is improved thanks to both improved IPC and higher clock speeds. There's improved branch prediction, and wider decode and execution engines. You also get two extra efficiency cores—six in all, but the same four performance cores. The GPU sticks to ten cores, albeit tweaked with Dynamic Caching, and hardware-accelerated ray tracing. In the new iPad Pro, the new silicon is partnered with what Apple claims is the world's most advanced display: the Ultra Retina XDR, a dual-layer OLED panel. There's also a 'pro' camera system, including a LiDAR scanner, 12MP still, and 4K video.

Apple claims the M4 can match the M2's performance while using half the power, as well as the 'leading' laptop chip, while consuming a quarter of the power. That chip is the Intel Core Ultra 7 155H. Obviously, there is a strong AI angle. The M4's neural engine is capable of 38 TOPS. Apple has the red and blue teams comfortably beaten, although Qualcomm's 45 TOPS Snapdragon X Elite is no slouch. More immediately important is the single-core Geekbench score—the M4 reached over 3,700, leaving Intel's Core i9-14900KS behind at 3,300. That means the tablet is now mightier than the desktop, sort of. If we switch to multi-core, then the 32-core Intel trashes it. Still, for a tablet, that's impressive. The M4 iPad Pro starts at $999, and if you play with the configuration, ticking all options, it tops $3,000. **–CL**

Fat New HDD Drives



EVERY TIME WE THINK THE magnetic hard drive is dead, new life is breathed into them. We haven't seen a new 2.5-inch drive for years, the format seemingly peaking at 5TB. However, Western Digital has squeezed an extra terabyte in. Its new 6TB versions are available across WD's external My Passport range—four in all, as well as ScanDisk's ArmorATD. Prices range from $185 to $230, depending on the enclosure and compatibility. This is, according to WD, enough to store 150 AAA gaming titles. The drive is taller than the 5TB version, hence it's external rather than internal, not that there are many laptops with spinning drives anymore.

More useful, perhaps, are big 3.5-inch drives, as the last three HDD manufacturers fight for what's left of the market by building the biggest drives. Toshiba is planning drives of over 30TB, and claims to have demonstrated working 32TB and 31TB drives using HAMR and MAMR (Heat Assisted Magnetic Recording and Microwave Assisted Magnetic Recording). The 32TB model has ten platters, while the 31TB uses 11—the first to do so. It has plans for 35TB by 2025, and 40TB in 2026. Conventional magnetic recording tops out at a capacity of around 22TB, and the three players are in a race to get the new recording methods into drives for the data center business. Seagate managed this with its 32TB HAMR drives last year, and has plans for 30TB. Western Digital has a 28TB drive, and plans for 36TB HAMR drives. If you want a consumer version, you'll have to wait, as the data centers will take everything built for the foreseeable future. **–CL**

New ChatGPT



OpenAI has released GPT-4o. The 'o' is for omni, hinting that this fast new multi-modal version of the AI bot does a lot more than chat. It uses the same LLM (Large Language Model), but is a lot more potent. The original has a latency of about three seconds—reasonable for text chat, but too sluggish for speech. GPT-4o reduces that to a level suitable for verbal and visual prompts in real time, as the video demonstration proved. The system is shown a room and then asked to guess what might be going on. It guesses that the room is rigged for video work. It was then told an announcement was going to be made. It correctly postulates that this might involve OpenAI (the demonstrator is wearing a branded top). This was all pre-prepared, but still spooky. OpenAI claims that it is better at audio and visual translation than all the current rivals. The speed of AI development remains dizzying. **–CL**

RTX 5080 to come first?

Nvidia usually launches a new GPU family with a bang. Its next GPU architecture is Blackwell, and is expected to appear this year. Nvidia has shown a 2025 roadmap, but nobody appears to believe that. The 4000-series Lovelace cards were stunning, but Nvidia's clumsy handling of their price and configurations knocked their appeal. Blackwell is hotly anticipated, and we'd love to see it before next year. But what Blackwell cards could land first? Early rumors suggested all we may get is an RTX 5090. More recently, that's changed to the RTX 5080, with the biggest gun saved for next year. Since AMD isn't providing hot competition at the top level, Nvidia isn't under any pressure to drop the 5090 first, but we still wouldn't be surprised to see both 5090 and 5080 announced together. Indeed, there is a small chance that by the time you are reading these words, Nvidia will have pulled the covers off something at the Computex trade show in Taiwan. **–CL**



Jarred Walton

TECH TALK

For Sale: Cheyenne Supercomputer

IF THERE'S ONE THING WE KNOW about PC hardware, it's that it becomes outdated. The Cheyenne supercomputer is testament to the rapid improvements over the past decade in the world of extreme scalability, coupled with a warning about things not always going as planned. Apparently, ongoing reliability, repair, and maintenance issues reached the point where the best option was to pull the plug and start afresh.

Deployed in 2016, Cheyenne was the year's 21st fastest supercomputer, with a score of 4.79 petaflops. Today, it's number 160 on the Top500 list—or was prior to being decommissioned. While it's not clear how much it cost, it replaced one that was around $25–$30 million, and its Derecho replacement is an HP-built setup that cost $35–$40 million. It seems reasonable, then, that Cheyenne fell in the $20–$40 million range. Eight years later, it sold at auction for $480,085.

It's interesting to read the auction notes, which state that "the system is currently experiencing maintenance limitations due to faulty quick disconnects causing water spray." This on its own wouldn't be terrible, except that approximately one percent of the 4,032 nodes were experiencing ECC memory errors. Washing its hands in the 150 gallons or so of propylene glycol coolant, the NCAR-WY Supercomputer Center decided to let someone else worry about parting things out.

The 32 petabytes of storage that the system used aren't included, but there are 14 E-cells, each containing two racks of quad-node server blades. There are 8,064 Intel Xeon E5-2697 v4 processors, 4,890 64GB DIMMs, plus power supplies, cooling, motherboards, networking switches, and more. There are also two management racks that added 52 1U servers and 8TB of DRAM. Altogether, the supercomputer weighs around 26,000 pounds.



The gulf between Cheyenne and modern supercomputers shows how far things have come



Cheyenne began service in 2016. Ultimately, it was sold at a fraction of the original cost.

The gulf between Cheyenne and modern supercomputer hardware shows how far things have come since 2016. Cheyenne used around 1.727 MW of power fully assembled, or around 2.77 petaflops per megawatt. Its Derecho replacement delivers roughly twice the computational power (10.32 petaflops), though it also includes 382 Nvidia A100 GPUs. There's a discrepancy between what NCAR says about Derecho and the Top500 result, however, as it's supposed to be a 19.87 petaflops supercomputer. With a 40 percent higher power draw than Cheyenne, that would yield 8.22 petaflops per megawatt.

Contrast that with the fastest supercomputer today. The AMD-based Frontier supercomputer holds pole position, with 1,206 petaflops of compute and a power use of 22.79 MW—nearly 53 petaflops per megawatt. AMD's El Capitan supercomputer should be finished in the near future, providing roughly double the performance of Frontier. It's not all about raw compute, however, as the Green500 list ranks the most efficient supercomputers. The current leader, JEDI, isn't even as fast as Cheyenne in raw compute, boasting 'only' 4.50 petaflops. However, its power draw is only 67kW—about four percent of the power consumption of Cheyenne for the same level of performance.

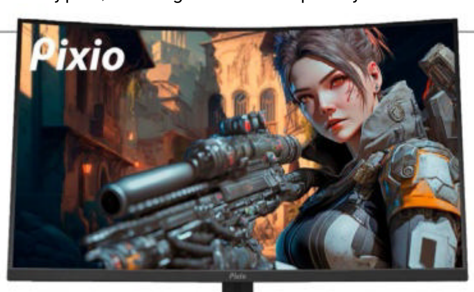
These figures use LINPACK results that focus on FP64 compute, however, and a lot of supercomputers are turning toward AI calculations using FP16 or FP8 operations. New supercomputers sporting Nvidia Grace Hopper superchips will bring 200 exaflops of AI compute within the next year. No wonder Cheyenne got kicked to the curb.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

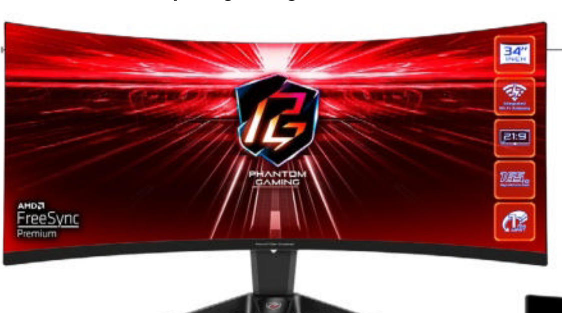
THE BEST GAMING MONITORS

WHILE MOST PC COMPONENTS have been getting pricier, many gaming monitors are cheaper. $250 buys you a lot more than it did five years ago, though a new class of OLED panels has made things pricier at the top end. In between, there's more choice than ever before, including resolutions, aspect ratios, panel types, backlight tech and plenty more.



5 PIXIO PXC277 ADVANCED

Don't know Pixio? Seen the pricing? Don't panic. Corners haven't been cut where it counts. It feels a bit cheap, but looks slick enough, and when it comes to image quality and gaming experience, there are no horrors. You get a 1440p VA panel, 1ms response, and 165Hz refresh. It's not true HDR, topping out at 320 nits and lacking local dimming, but that's fine. **$240, www.pixiogaming.com**



4 ASROCK PHANTOM PG34WQ15R2B

A contrasty VA panel, plenty of backlight punch if you run it in HDR mode, reasonable pixel response, and high enough refresh for most gamer's purposes. $350 barely touches the sides when it comes to graphics cards these days, but here it buys you 34 inches of real estate, 165Hz refresh rate, 1ms response, and even HDR support. Nice for ASRock's first gaming panel. **$350, www.asrock.com**

3 GIGABYTE M28U

Looking for a slightly larger alternative to that LG panel for not much extra cash? Try this alternative. Gigabyte's more affordable 4K monitors go down a treat—they're fast and bright, and you even get a USB-C hub thrown in. Between the resolution, 144Hz refresh rate, and IPS panel, it's a great all-rounder for 4K. Even beyond PC gaming, an HDMI 2.1 port offers 120Hz gaming for consoles, so it's quite the package. **$429, www.gigabyte.com**

2 LG ULTRAGEAR 27GR93U

The LG UltraGear 27GR93U is LG's IPS tech at its best. It's absolutely gorgeous, with colors that are accurately calibrated, crispy 4K visuals, and a zippy refresh rate. You will need a mighty graphics card to run this UltraGear gaming monitor at its fullest, of course. It runs up to 144Hz, which is a tough task even with modern GPUs. Upscaling will help with that, meanwhile the 4K precision makes this a great panel for getting serious stuff done, too. Overall, this is a very strong all-rounder, even if it comes at quite a price. **$425, www.lg.com**



1 MSI MPG321URX

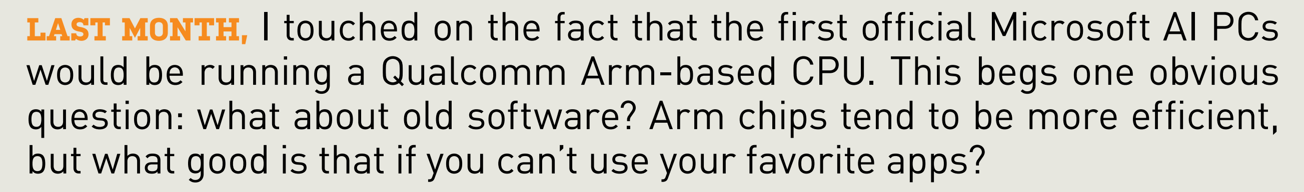
Another day, another 32-inch, 4K, 240Hz QD-OLED stunner. Except this one's cheaper and every bit as good as the competition. An easy choice? For once, yes. This offers the same Samsung-sourced QD-OLED panel as more expensive monitors, including the Asus ROG Swift OLED PG32UCDM, the Alienware 32 AW3225QF and the Gigabyte Aorus CO49DQ, but it's hundreds of dollars cheaper. As no-brainer recommendations go, this is as straightforward as it gets. **$899, www.msi.com**



Jeremy Laird

TRADE CHAT

How to emulate x86's success



LAST MONTH, I touched on the fact that the first official Microsoft AI PCs would be running a Qualcomm Arm-based CPU. This begs one obvious question: what about old software? Arm chips tend to be more efficient, but what good is that if you can't use your favorite apps?

The CPU cores in Apple's new M4 chip are scary, as in scary fast. Seriously. The M4 cranks out about 3,800 points in Geekbench 6 single core. That compares with roughly 3,300 points for an Intel Core i9-14900K. Remember, that's an M4 running in a tablet. It's only in the iPad Pro for now, not in any Mac computer.

The point is that you can forget about assuming that Arm chips are efficient but feeble. They can be competitive and then some for raw performance. The problem is that you can have all the performance in the world, but it doesn't count for much if there's no software to run. Historically, Microsoft hasn't done a great job of supporting old x86 software on Windows for Arm chips.

Supposedly, it's going to be different this time. For starters, some key apps, including Chrome and Adobe Photoshop, will be available in native Arm format. For a lot of users, native Chrome alone is almost enough. For everyone else, emulation, performance, and efficiency will be key.

Critically, there are two aspects to any attempt to emulate another CPU architecture, in this case Arm emulating x86, the software, and the hardware. The upcoming 24H2 update for Windows 11 has a new translation layer known as 'Prism', which will convert code on the fly from x86 to Arm.

Inevitably, there's another comparison to be made with Apple and its Rosetta 2 emulation layer, which was introduced when the Mac itself moved away from Intel x86 CPUs to Apple's in-house Arm silicon. But the same applies to the hardware side of the equation. Apple's Arm-based chips have hardware features and optimizations designed to improve x86 emulation.

> Some key apps, including Chrome and Photoshop, will be available in native Arm format

For instance, the way Arm and x86 order memory is based on different models, known as weak and strong respectively. Apple silicon incorporates both models, and that apparently makes a big difference for performance and efficiency when emulating. It's not clear what, if any, hardware elements the X Elite chip has for improving emulation.

However, there's one reason to think there may be some. The CPU cores in the X Elite were actually designed by a startup called Nuvia, which Qualcomm snapped up in 2021. But here's the real kicker: prior to co-founding Nuvia in 2019, its CEO, Gerard Williams, was none other than Chief CPU architect at Apple for nearly a decade. The company was staffed by other former Apple engineers involved in the company's transition to Arm. It's safe to say that Nuvia, and therefore Qualcomm, knows all about what it is in Apple silicon that makes emulation run so well.

Exactly how good the X Elite will be remains to be proven. Qualcomm has previously claimed that even games will "just work" on the X Elite, and we recently found that the MacBook Air can be surprisingly good for gaming in some narrow scenarios. But there's much to be proven.

The 7th Gen Microsoft Surface will reveal just how well the Snapdragon X Elite can emulate x86 software.

Qualcomm can make a fantastic chip for emulating old code, but it won't be any good if Microsoft doesn't play its part. Put simply, Qualcomm doesn't control the entire stack, and that's a clear disadvantage compared to Apple. All that said, as I explained last month, Microsoft seems to be pretty tight with Qualcomm right now. It has chosen the latter to partner with and promote the first AI PCs, something that Intel and AMD can't be happy with at all.

It certainly seems like Microsoft is keen to promote the Arm platform, which implies that it might have put the work in to get x86 emulation running well. It won't be long before we find out. By the time you read these words, the first laptops with the X Elite chip will be out, and the tech community will be poring over every aspect of performance. Things are certainly getting interesting.

Six raw 4K panels for breakfast, laced with extract of x86... Jeremy Laird eats and breathes PC technology.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> VPN vulnerability
> Application tabs
> Podman acceleration

Are VPNs toast?

I've been reading a news story on the TunnelVision vulnerability for virtual private networks. Apparently, this—excuse the pun—tunnel-sized hole in VPN security has existed since 2002. It says the vulnerability allows attackers to force VPN apps to send and receive at least some of your traffic outside of the encrypted tunnel. The claim is that you're only safe when the VPN runs on an Android device or Linux PC. Is this true, and if so, does it mean the VPN networks I've been using for all these years have been utterly useless in all that time?
—Caitlin H Tracey

THE DOCTOR RESPONDS: The headline of this vulnerability does make for grim reading. That said, in practical terms, the risk can be minimized and even eliminated completely. That's because this vulnerability targets the network you're connecting through. It makes use of a weakness in how DCHP servers, which allocate IP addresses to devices that aren't configured to manually set these themselves, work.

The weakness is known as Option 121, and allows networks to change the route traffic takes to certain IP addresses or websites, basically giving bad actors the opportunity to reroute traffic outside of the VPN's encrypted tunnel.

The attack requires someone to have administrative control over whichever local network you're connecting to, which is the first piece of good news. If you connect through your phone's cellular network, or you're using a VPN at home through your own local network, then you should be immune from this type of attack.

The risk comes when you connect through third-party Wi-Fi networks, such as public hotspots. If you rely on the DHCP server to provide you with an IP address to connect to that network, you would be vulnerable if the network itself has been configured to use Option 121 to re-route traffic. There are, however, workarounds.

First, check your VPN provider doesn't offer protection against this kind of attack. For example, ExpressVPN's Network Lock switch is designed to protect against attempts to force your traffic to bypass the VPN. Therefore, if the lock is switched on, you're safe now—and were in the past, too. Any attempts to bypass the VPN would result in an error or blank webpage. Even if your VPN provider offers such a kill switch, make sure it's robust enough to block the TunnelVision vulnerability.

A fiddlier workaround involves connecting to the local network to obtain an IP address and other network details, then switching your network settings so they're manually configured. You can use the same connection details, but because you've specified these yourself instead of using the DHCP server, you're protected from any bad actor.

As for Android and Linux users being safe, that's not quite true. You're certainly protected against TunnelVision when connecting through your Android mobile, because the platform doesn't support DHCP Option 121. However, while Linux has a setting that minimizes the effects, it's not immune thanks to a side channel.

One final thing: if you followed last month's feature to set up a WireGuard VPN server to allow you to dial home into your network, you're immune too. That's because the only way into it is through your VPN tunnel, so any traffic re-routed outside the VPN can't get to it.

Tabs for any app

I have so many application windows open it can be a real pain switching between them all. Do you have any tips or tools that could help me bring a bit of order to the chaos? **—Gerald L Bromberg**

THE DOCTOR RESPONDS: The Doc's recommended solution, which he uses on a day-to-day basis, is a program called TidyTabs (www.nurgo-software.com/products/tidytabs). As the name implies, it basically lets you merge multiple application windows into a single tabbed window. It's what Microsoft's Sets feature would have offered in Windows 10 had it not been canceled back in 2019.

There are two versions available—one that's free for personal use, and a professional license for $29.

↘ submit your questions to: doctor@maximumpc.com

The big restriction in the free version is that you can only group three windows together at any one time—once installed and running, roll your mouse over the top left-corner of a window to reveal a small colored tab. Simply click and drag this on to another window to group them together—if the windows haven't been extended to the full height of the screen, you'll see semi-translucent tabs appear above the window when it's in focus with the name of the app or open document on each one. Just click a tab to switch to it, or click and drag the tab to separate the windows again.

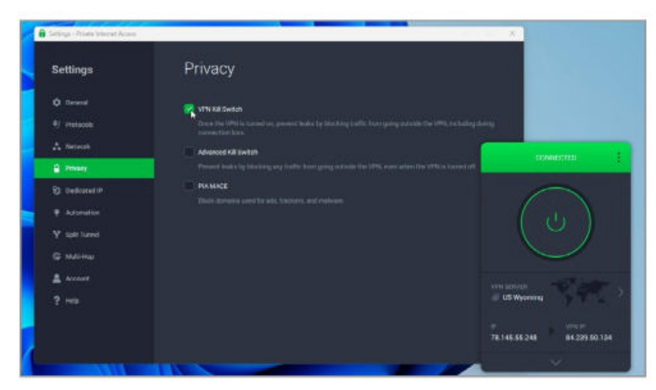
You can combine windows from different applications, allowing you to group items by whatever criteria you choose. You can also create whitelists and blacklists to automatically set up tabs for certain windows, as well as exclude certain applications from working with TidyTabs.

The free version gives all the core functionality you need to evaluate TidyTabs, but upgrading to the Pro version does more than simply remove the three-tab limit. You gain access to smart grouping options, which make it easy to combine windows from the same application (great when working on multiple Word documents, for example). You also get to choose a tab color scheme, rename or reorder tabs, define hotkeys, and open a file in a window by dragging it on to its tab. If you're juggling lots of open windows, then TidyTabs is definitely worth giving a go.

Jellyfin Podman problem

I've migrated my Jellyfin media server from a native instance on my Linux server to a Podman container. Everything appears to be working okay, except I cannot get it to use hardware transcoding. Whenever it's unable to direct play files, it fails with an error unless I disable the feature, at which point it'll transcode using the CPU. What am I doing wrong?

—Edward Sundberg



Most decent VPN providers offer a kill switch.

THE DOCTOR RESPONDS: The Doc was able to get transcoding working in both Jellyfin and Plex containers with what can only be described as a bit of a botch job. It basically boils down to giving the container access to the GPU via the /dev/dri/renderD128 directory. By default, your container is unable to access this folder because of a combination of user restrictions on that folder with the way user namespace mapping works in rootless Podman containers.

Access to the folder is through the 'render' group, which has the necessary permissions. On a native Jellyfin install, a user is created that's automatically added as a member of the group. Docker users are told to use the '--group-add' flag to link Jellyfin, but it had no effect on either Plex or Jellyfin in our experiments.

Instead, the Doc recommends taking some liberties with security and widening access to the /dev/dri/renderD128 directory. You can test this with the following command, which changes user permissions to allow all users to read and write to the directory:

```
sudo chmod -R 666 /dev/dri/
renderD128
```

Now, as long as your Jellyfin Podman script has the following line, you should be able to enjoy the benefits of hardware transcoding:

```
--device=/dev/dri/
renderD128:/dev/dri/
renderD128:rwm \
```

Test by playing back a video that requires hardware transcoding—for example, by using your mobile phone and changing the playback settings to reduce the bitrate. Confirm transcoding is taking place from the Jellyfin server's web-based dashboard (click the 'i' button under the device's entry), then keep an eye on CPU usage—it should be 30-40 percent rather than 95-100 percent when CPU transcoding is taking place. Cockpit users can monitor CPU usage from the Overview section.

Once you've confirmed the fix works, you can enjoy hardware transcoding—until you restart your server, as this is one of those permissions that doesn't survive a reboot. You can either manually run the 'chmod' command after every reboot in future, or you can make it stick by editing a single file:

```
sudo nano /lib/udev/
rules.d/50-udev-default.rules
```

Locate the following lines:

```
SUBSYSTEM=="drm",
KERNEL=="renderD*",
GROUP="render",
MODE="0660"
SUBSYSTEM=="kfd",
GROUP="render",
MODE="0660"
```

Change '660' to '666' in both lines, save the file and exit. The fix is now permanent, and hardware transcoding should always be available going forward.

Remote inspection

A friend is offering me his old gaming PC for what he says is a 'knock-down' price. He lives about 30 miles away, so I don't want to travel over to view it before I've done a bit of due diligence. He doesn't know much about PCs, so ideally, I'd like to check out its spec remotely. Any ideas how this could be done?

—Timothy Ramos

THE DOCTOR RESPONDS: Why not set up a video conference with your friend using a tool that allows desktop sharing? Most tools support this, including Microsoft Teams. Once the meeting is set up, ask your friend to look for an option to share his desktop with you, then walk him through accessing Settings > System > About so you can look. If you like it, ask him to download and run the portable version of HWiNFO (www.hwinfo.com). Get him to launch the tool and make sure both Sensors-only and Summary-only are unchecked before clicking Start. This will let you take a deeper dive into his system.

Alternatively, if you'd rather be left alone to check the PC yourself (and your friend is happy to let you poke around), suggest setting up a Quick Assist session in Windows. Launch the tool and click 'Help someone'. Sign into your Microsoft account, then ask your friend to open Quick Assist on his PC. Communicate the security code on your screen to your friend, who should input it at his end, and click Submit. Once connected, request to take full control. You're now free to perform whatever checks you need to learn what you can about your prospective purchase.

TINY TOWER ULTIMATE POWER
THE TRANSPLANT BUILD

Zak Storey takes the RX 7900 GRE out for a spin in a tiny E-ATX Tower

WHEN IT COMES TO the ITX form factor, most will end up in one of two camps. Either you love them because of the minimalist aesthetic, small footprint, and that basic concept of absolute power in a ridiculously small build. Alternatively, you hate them because of the lack of connectivity, limited case choices, and often poor cooling as a result.

It's one of the most controversial form factors out there. With components getting larger, more power hungry, and requiring more cooling to get the most out of them, it's becoming increasingly difficult to find support for it across the board as we move from generation to generation.

But what if we were to tell you there was another way? What if we could mix the very best of both worlds? A small form factor case that didn't compromise on cooling, with full E-ATX motherboard support, and an intuitive layout that allowed you to squeeze in some serious power, without sacrificing in any one area? Well, that would be perfect, right? But surely it doesn't exist?

Well then, with 24 cores, 32 threads, 32GB of 6,000 MT/s memory, one of the best value 4K GPUs you can pick up right now, a super-premium cooling solution, 1200Ws of power delivery, and no less than 6TB of PCIe 4.0 and 5.0 storage, all cooled via six 120mm fans and a 360mm radiator, this build here ticks all of the above boxes and then some. What's more impressive is that it fits all of that in a tower chassis that measures, at its smallest, just 15.6 x 8.5 x 16.1 inches. To put that into perspective, at *Maximum PC*, our first ever ITX liquid-cooled PC was built inside the incredible NZXT Manta, a case that by contrast measured 16.7 x 9.6 x 17.7 inches—over an inch larger in every measure.

Well then, ladies, gentlemen, friends, colleagues, and everyone else in between, *Maximum PC* is proud to present the Tiny Tower Ultimate Power build. Let's geodesically weave our way into the feature, shall we?

INGREDIENTS

PART		PRICE
CPU	Intel Core i9-14900K	$549
Motherboard	Asus ROG Maximus Z790 Dark Hero	$595
CPU Cooler	Phanteks Glacier One 360D30 White	$170
RAM	32GB (2x16GB) Crucial Pro Overclocking DDR5 @ 6000 C36	$105
SSD1	1TB Crucial T700 M.2 PCIe 5.0 x4	$172
SSD2	2TB Kingston Fury Renegade M.2 PCIe 4.0 x4	$173
SSD3	2TB Lexar NM790 M.2 PCIe 4.0 x4	$147
GPU	Sapphire Pulse Radeon RX 7900 GRE 16GB	$550
Case	Geometric Future M4 Caliburn ATX Mid-Tower	$109
PSU	1200W Corsair RM1200x Shift 80+ Gold	$206
120mm Fans	Phanteks M25-120 PWM D-RGB Fans 3 Pack	$30
TOTAL		**$2,806**

PRICES CORRECT AT THE TIME OF PUBLICATION



https://content.jwplatform.com/videos/e7X8CgNq-u2lN49He.mp4
Please type this URL into your browser if the link is broken

POTENT PC PART PICKS FOR PREMIUM PERFORMANCE



CPU

Intel Core i9-14900K $549
www.intel.com

Time and time again, we keep coming back to the Intel Core i9-14900K, and with good reason. At its core, this build is the very heart of the *Maximum PC* testbed. It's our go-to chip for GPU, RAM, and SSD testing, and delivers incredible performance for the price. It's effectively the pinnacle of what Intel has managed to achieve with its Rocket Lake architecture.

It's not perfect, and if you've kept your ear to the ground on this one, you've likely seen news articles regarding motherboards producing pretty aggressive overvolts and clock-speed boosts. However, you can now pick up an Intel default performance profile in most mobo BIOSes, and even with that slight drop in overall potency, the 14900K still delivers supreme CPU performance, circumnavigating any potential bottlenecks you can imagine for any other component in your build. You're still likely to see those 100 C running temperatures and high clock speeds, but it'll at least be a touch more stable.

Fun news cycle data aside, the 14900K has some serious hardware at its core (ha, puns), including eight performance cores, with hyperthreading, plus 16 efficient-cores, for all of those low-priority application processes that need managing. Combine that with 36MB of mixed smart-cache, and the 14900K quite happily dominates any task you throw at it.

Motherboard

Asus ROG Maximus Z790 Dark Hero $595
www.asus.com

It's a bit odd when your motherboard costs more than your CPU, and this one has arguably been the cause of a number of headaches for us lot in the labs over the last few months.

On the surface, it's an incredible piece of hardware. One PCIe 5.0 M.2 slot, four PCIe 4.0 M.2 slots, a phenomenal amount of USB connectivity both in the rear I/O and on the board itself. Wi-Fi 7 as standard, 2.5Gb Ethernet, and a seriously hefty 20+1 VRM solution as well. It's given Asus the opportunity to push these chips to the nines when it comes to performance, and that has certainly come with some drawbacks in terms of system stability (we're looking at you, Core i7). Still, with a few tweaks here and there, and some adjustments to some of the Asus AI auto-overclocking nonsense in the BIOS, the Z790 Dark Hero is a great board for any connectivity aficionado.

The only thing that does look a bit awkward (for a $595 motherboard) is that weird 'Aura Grid' rear I/O LED thing. It's not a display, so don't get your hopes up—this isn't a Formula board, unfortunately—but you can turn it off in the BIOS, and leave yourself with a clean mirrored finish here instead.

CPU Cooler

Phanteks Glacier One 360D30 $170
www.phanteks.com

For this build, we wanted to step away from all of the crazy display AIOs currently out there topping $300, complete with messy cable management systems and nightmarish surrounds, and instead opt for something a little more low-key. This time, we've gone for the Phanteks Glacier One 360D30 in white.

There's no pomp or fanfare here—just simple, clean, elegant design, mixed with an intuitive mounting system, and one seriously hardcore backplate. It comes with support for pretty much every socket since the LGA115x series and above, and also includes a set of Phanteks' daisy-chainable D-RGB fans.



STEP-BY-STEP P.22

It's a fantastic pick, and performance on those fans in particular is killer, clocking in 3.01 mmH2O and 64.3 CFM at full tilt, while still only registering 30.2 dBA at maximum RPM. That's not too shabby. Impressively, we found that the pump was actually the noisiest element once we had it all set up to our fan curves correctly, and even then, once the system got a little settled, it soon faded away. We've gone with white this time to provide a little contrast against the dark black of the motherboard and its supporting components. It's a small change, but it really gives the build a bit more of a three-dimensional feel because of it, particularly when you start illuminating that interior with a touch of LED lighting.

RAM

32GB (2x16GB) Crucial Pro Overclocking DDR5 @ 6000 C36 $109

www.crucial.com

It was only the May 2024 issue that we used this same Crucial kit in another build, that one featuring the RTX 4080 Super among other things, and we've turned to it and Crucial once more for one simple reason: memory profiles.

Sounds mundane, right? We've got all these illuminated parts internally, and so much going on, and yet, somehow we've gone with a bland low-profile memory kit that clocks to just 6,000 MT/s? Well, as this build is more transplant than a fresh take, and its core is predominantly our testbed, versatility is key.

A good review, and a good set of benchmark results, relies on consistency. Testing CPUs in particular requires every other component in that loop be of a similar caliber. GPU, SSD, motherboard if possible, but the biggest challenge is memory. If you're using two very different kits of memory for both Intel and AMD, you're immediately going to invalidate your results. Searching around for two similar or identical kits, with timings that are parallel to one another, with the same frequency and capacity, can be challenging. For a long time, manufacturers produced kits with only either Intel's XMP settings or AMD's EXPO settings embedded on them. Got an AMD system? Buy this kit, but you'll be up a certain creek without a paddle if you swap to Intel later down the line.

Excuses were used about storage space on the DIMMs (for timings—can you feel our frustration there?), but finally, Crucial broke the mold, and put both Intel and AMD profiles on a single kit of memory. That's why the Crucial Pro Overclocking kit is so valuable. 32GB of pristine DDR5, at 6000 MT/s (the sweet spot for AMD and Intel) plus consistent timings between both platforms? Consider us sold, and for only $109 as well.

SSD 1

1TB Crucial T700 M.2 PCIe 5.0 $172

www.crucial.com

Sometimes, the fastest parts aren't the most useful parts when it comes to building a decent testbed, and nowhere is this more apparent than with our OS SSD. Because we're utilizing that Asus Dark Hero as our motherboard of choice for SSD, RAM, GPU, and Intel CPU testing, we needed an SSD that'd fit comfortably in that PCIe 5.0 slot and one that you could remove from its heatsink.

With that in mind, we've gone with the T700 over the T705 with one reason in mind: you can remove it from its heatsink. Sadly, although the T705 is significantly faster than the T700, its lack of an easily removable heatsink makes it a challenge, particularly if we want to secure it in place and take advantage of the Z790 Dark Hero's gargantuan SSD heatsink.

It's still a good drive, with top-tier sequential performance, and decent



STEP-BY-STEP P.22

random 4K (pretty much in line with the bulk of that generation of PCIe 5.0 drives), but it's not the quickest. That said, 1TB at just $172 represents good value right now.

SSD 2

2TB Kingston Fury Renegade M.2 PCIe 4.0 $173

www.kingston.com

Our second key drive is the Kingston Fury Renegade M.2 PCIe 4.0 SSD. This is where we store all of our software and games for the copious amount of benchmark runs we perform here at the mag and when testing hardware.

We've waxed lyrical enough about the Fury Renegade over the last few issues, but to cut a long story short, its got some seriously intuitive engineering behind it, coupled with a significantly chonky full-fat DDR4 cache, giving it quite the competitive edge in random 4K performance versus even some of the larger PCIe 5.0 drives out there right now. Yes, it's predominantly designed for consoles like the PS5, but its pure performance grunt makes it a surefire pick as our secondary drive.

SSD 3

2TB Lexar NM790 M.2 PCIe 4.0 $147

www.lexar.com

Three SSDs? In one build? Impressively, we've still got space for another two SSDs if we want with that motherboard. Still, our third SSD drive (predominantly operating as a backup drive, and for any tertiary games we might need to download, or video content we may need to store), is the rather impressive 2TB Lexar NM790 PCIe 4.0 SSD. For testing purposes, we'll be reporting on this drive in particular, as it's a seriously top-spec PCIe 4.0 SSD, but with the caveat that it's currently available at an incredibly low $147.

That's phenomenally cheap for a drive of this size on the PCIe 4.0 standard, and given that we know the results as we write this, you won't be disappointed if you do pick this up for your primary drive.

GPU

Sapphire Pulse Radeon RX 7900 GRE 16GB $550

www.sapphire.com

Peak RDNA 3 GPU—that's how you should see the RX 7900 GRE. Also, we're starting to wonder if AMD's going to run out of suffixes with the rate it's releasing these GPUs. The RX 7900 GRE is designed to fit nicely in the power vacuum laying between the 7900 XT and the 7800 XT. Why isn't it called the 7900? Good question.

That said, for its reasonable $550 price tag, you get access to 80 Compute units, 5,120 shader cores, 160 Tensor cores, and 80 ray tracing cores, as well as a fairly healthy 2,245 MHz boost clock. It also packs in 16GB of VRAM to round it all off.

There's a lot of similarities between how the 7900 GRE has been handled and the RTX 4080 Super. On the one hand, compared to the 7800 XT, there's a not insignificant hardware bump, particularly going from 3,840 shader cores up to 5,120 (25 percent more, if you're counting). Yet, the clock speeds are actually significantly lower than the 7900 XT and the 7800 XT, both of which break that 2,400 MHz barrier, while the GRE slides in at just 2,245 (about an eight percent drop, at least on reference cards), which will inevitably mute that hardware bump we've seen.

Either way the GRE looks to be the perfect entry-level 4K gaming GPU or top-tier 1440p graphics card, if you've got that kind of cash, and don't mind the slightly less potent ray-tracing performance.

Case

Geometric Future Model 4 Caliburn ATX Tower $109

www.geometricfuture.com

Here, we have that 35L masterpiece, the Model 4 Caliburn. This isn't the first chassis we've seen from Geometric Future, and likely won't be the last either, as the case manufacturer continues to impress us with its incredibly innovative design full of clean, crisp details.



The Model 4 has an incredibly small form factor, that much we've already established, but you may have spotted we listed 'in its smallest configuration' as a caveat, as it can have four separate configurations, depending on how you want to manage your build. Simply by raising the roof and its associated bracket, or removing a plate here and there, you can dramatically adjust everything from SSD placement and PSU support to vertical GPU mounting and radiator support, all without losing any of those beautiful style elements, including the L-shaped smoked glass window, mirrored front panel, and perforated ventilation. Similar to the Model 8 we looked at in the May 2024 issue, the Model 4 takes advantage of a similar chimney airflow design to alleviate heat build-up, leaning into natural convection rather than fighting it, as you'd find in other cases.

For top-line stats, you get up to E-ATX motherboard support (although we'd stick with ATX for optimal cable management), up to 1x 360mm, 1x 240mm, and 1x 120mm radiator support, mounting locations for nine fans total, and PSUs (dependent on install orientation) up to 180mm in length. It'll also house up to four x 2.5-inch SSDs, or 2x 2.5-inch and 2x 3.5-inch hard drives instead, and lastly, GPUs will clock out at around 405mm long, although slightly shorter will make your life a little easier if you're running an AIO in the floor. It's a lot of case for $109, that's for sure.

PSU

1200W Corsair RM1200x Shift 80+ Gold $206

www.corsair.com

Big graphics cards require big power supplies to support them, and with the way things are going (bearing in mind that Nvidia's 12VHPWR connector/cable and the initial design of the 4090 was to support up to 600W of power draw before manufacturers kicked up a fuss), we don't see that changing any time soon.

For a solid testbed, then, having a big PSU is key. To that end, we're sticking with the RMx Shift. It's been a staple in a number of our builds now, and will likely remain so. Corsair has built the Shift a little different, as it's shuffled all of the modular power connectors to the side of the unit, rather than the rear. It actually works rather well in our build here (you'll see why in a bit), but it can lead to some compatibility issues with other cases, so do bear that in mind if you decide to make the jump to the shift life.

Why the shuffle on the power connectors? Simply put, in any other traditional case, with the PSU in the floor, this will place the connectors right in front of you as soon as you remove the rear side panel on your chassis, meaning you don't have to fumble around, trying to disconnect or connect a power cable for that extra SSD you've just bought.

120mm Fans

Phanteks M25-120 PWM D-RGB Fans 3 Pack $30

www.phanteks.com

For our backup fans (or exhaust fans, in this instance), we've gone with a set of Phanteks M25-120 PWM D-RGB units in white. These aren't the most glamorous of solutions, but if we're honest, they still look great, and pack plenty of performance. Here's the thing, though: they're still A-RGB, and can daisy-chain into our D-RGB units on our AIO too, so it's all controlled off a single RGB header for ease of access.

On top of that, this triple 120mm kit here is just $30—a great price for a good quality fan kit. What's not to love?

MISFIT TOYS

LENGTH OF TIME: 2-3 hours
DIFFICULTY: Hard

This is probably one of the hardest builds we've had to create here at *Maximum PC*, and that's a heavy statement for us to make. After all, we're veteran builders here, with hundreds of published build logs to our name, and multiple liquid-cooled rigs under our belt, including a few in some seriously space-restricted cases.

Yet, throughout this process, working in the Model 4 had to be approached with an open mind. We've always been advocates of the notion that your build process should be fluid. Take a look at your chassis before you start installing anything. Try to identify where you might hit a snag or bottleneck. Think about your clearances, and where your hardware will sit. Would it be easier to install the fans first? Where will your cables go? Should you wire everything earlier or later, or chop off those front panel headers entirely?

System building at the upper-most level is an intricate puzzle. That's not to say that the Model 4 is a bad case, but If you're installing some seriously insane componentry, you're going to have to think like this. Mid-range and entry-level systems with smaller power supplies, less chunky GPUs, and smaller coolers will be easier to work around, but if you intend to push this chassis to its absolute limit, then buckle up, because it's going to take some thought.

Fortunately, whenever we thought a problem was about to occur, the Model 4 quickly pointed out a way it could adapt to that problem. More often than not, it was us overlooking a particular element of the chassis (and not reading the manuals that came with it) that led to the issues.

As for the core of this build, it's effectively a transplant; moving one testbed system over to another. Downsizing, without compromise, in an attempt to reclaim a bit of desk space, and build a kick-ass system that doesn't quite dominate the entire workspace.

HEART TRANSPLANT

Unlike our typical build order, with a transplant build, things are a little different. You'll likely recognize that system there in [**Image 1**]—that's our feature build from the May 2024 issue, with a few minor alterations to make it suitable for our testbed scenario. Yep, we ditched the NZXT board in favor of the PCIe 5.0-supporting Z790 Dark Hero—perfect for SSD testing and beyond. You'll also notice that we swapped those fans around on the AIO mounted to the 'rear' of the Model 8 to act as intakes instead, and shifted the Corsair iCUE Link H150i LCD block around by 90 degrees. The former was to help keep our cooling in check, and help while benchmarking GPUs (a couple of degrees won't hurt you and your build, but when benchmarking, consistency is key). As for the latter, that helped straighten out those tubes a touch, along with clearance with our larger GPUs.

Still, first things first: a complete disassembly of our Model 8 system. Removing the RTX 4080 Super, along with the memory, and removing the cooler, before finally getting the motherboard and the power supply out as well. We've left a few components in here, too. The CPU and the primary and secondary M.2 SSDs can stay put during the transfer.

An interesting snag here was on-board removal. We'd taken out all the screws securing it in place, but forgot the additional motherboard standoff screw underneath that big bulky PCIe 5.0 aluminum M.2 heatsink. Many frustrating minutes later, it clicked, and we removed the M.2 heatsink and that final screw.

With all the kit finally retrieved from the Model 8, we set aside the motherboard for later, making sure to install the NM790 into the PCIe 4.0 M.2 slot below the Kingston drive [**Image 2**]. One thing to note: you can see our motherboard's M.2 Thermal pads are getting a little battered. You can buy replacements from Amazon for around $10. This is highly recommended if you're an SSD reviewer, but less so if you're just changing SSDs now and again.

MAKING LIFE DIFFICULT

"Hey Zak, why don't you take a chassis with an incredibly compact internal layout, and use a bespoke shifted power supply that wasn't designed for it?" That's pretty much how you can sum up this next segment. The Model 4 has a unique side panel and chassis design. We, of course, did the usual teardown. The side window is an L shape of toughened smoked glass—simply lift that off at the hinges. The rear panel is a folded perforated structure that sits on top and slides into notches on the rear, secured up top with push pins.

You remove that via a tab at the top back of the case (just push it up and off). With that out of the way, you can then begin to configure your PSU solution. The PSU will sit at the front of the Model 4, and you can mount it in two orientations: one with the PSU power connector facing up (requiring you to raise the roof and rear radiator bracket), or one with the PSU

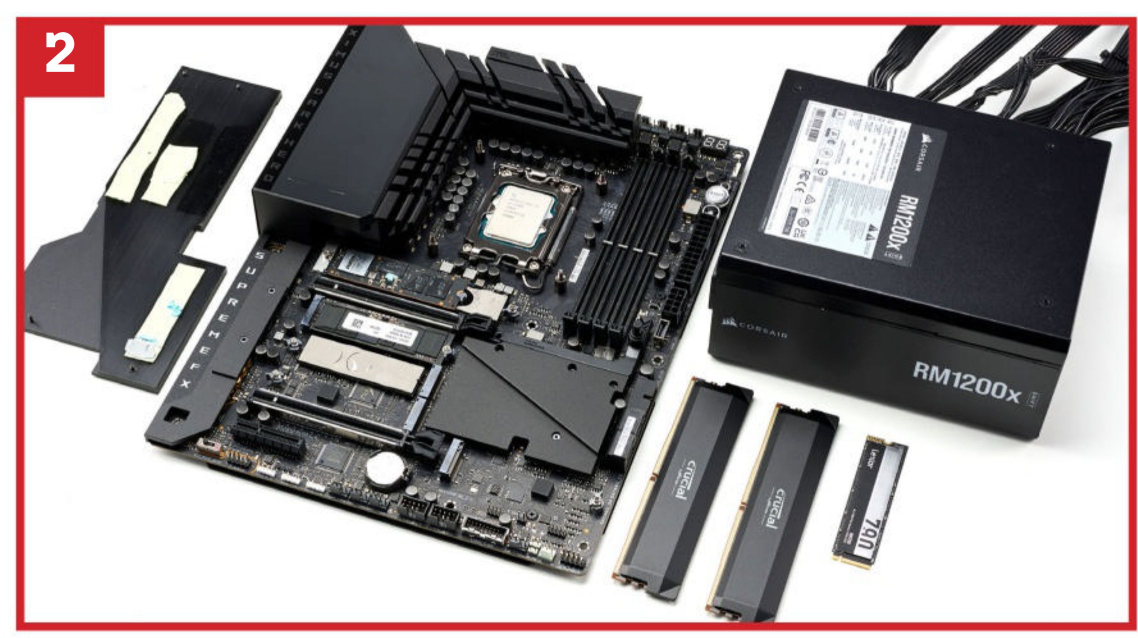
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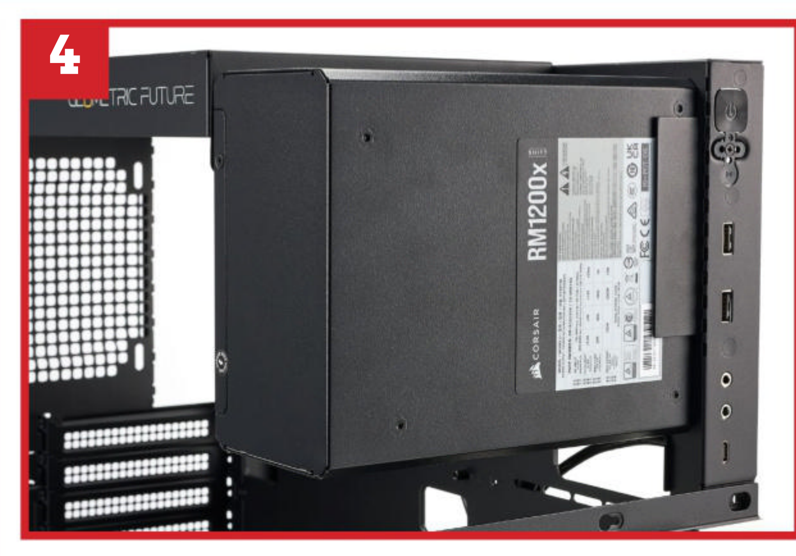
3






2
RM1200x
CORSAIR
crucial


RM1200x
CORSAIR
GEOMETRIC FUTURE


4
RM1200x
CORSAIR


5

power connector facing into the back of the chassis (to the right in [Image 3]). Either way, it'll require you to remove a number of panels to facilitate that, including that front mirrored panel. There are six screws that hold it in place—you can simply slide it out. It's a right-angled unit, and it took some manual reading and investigating to find out how to do that.

If you want to go the top connector route, you have to then remove a couple of screws in the rear of the case. Back there, you'll find a thumbscrew on a sliding mechanism that will let you lift up that rear metal housing for the radiator housing (the bit with the Geometric Future logo on it). Once that's up, secure it in place, and that's your new roof. Then, the L-shaped roof/rear panel will sit on and attach to that. It all looks flush, connects perfectly, and everything fits, but now you'll have that PSU power cable pointing up, ready to connect to the included passthrough.

Rather interestingly, although it's a tight squeeze, the RMx Shift is probably the best PSU for the job for a clean build. The power connector faces out to the rear of the case, and the Type 5 modular power connectors for your internal cables are facing down, ready to be cable managed through that rear cable hole. It is snug, though. [Image 4/5] .

CABLE MANAGEMENT

You'll have noticed at this point that we're going with the power supply first for this build. Clearances are going to be tight, so we know we need to take advantage of this as best as we can. Our build order will be power supply, initial cable management, motherboard in, followed with complete cable install and routing, then bottom CPU cooler in (with a test fit of the GPU), before finishing with the top fans, and lastly the GPU, before a final round of cable management.

So on we go [Image 6]. Here, you can see we're going ahead with that plan and have plugged in pretty much every cable we're going to need for our system. We've then threaded those cables through the cable management hole below, and wrapped them up as best we can with the included velcro straps that Geometric provides in an attempt to keep them tight and hidden out of the way. One thing to note: after this shot, we've actually gone back and added the 12VHPWR600 cable as well. We'll be tucking that away around the back of the chassis. It won't be used in this build, as the RX 7900 GRE still uses old faithful PCIe power connectors, but if/when we do swap back to an RTX card, it's going to help to have that connector there. But yes, cable management is going to be your friend big time on this build, particularly with that mildly awkward L-shaped back panel.

With our PSU now safely secured in the chassis, we've gone ahead and re-attached that front panel, making sure to get as many smudges on the glass as possible to annoy the photography team. It does look super clean though.

Installing the motherboard in the chassis was next on the list. We've already got the 14900K installed from our last system (as we're just transferring the motherboard), so that's not a problem. We're not sure what, but something was causing clearance issues with the board, not sitting quite flush with its rear I/O panel, and the mount-off screws. With the chassis laying on its side (admittedly mildly wedged up by a plethora of cables), we just couldn't secure more than three of the nine screws into it. However, with those three in, we placed the chassis upright, the board lined up, and we could install the other six screws [Image 7].

KEEP ON KEEPING ON

So, motherboard in (sort of—we didn't spot that we could install those screws until later), we got to work installing the cables. Interestingly, the ROG Dark Hero has an additional 8-pin PCIe power port located below the 24-pin. This is to help deliver additional power to the graphics card if it needs it. Honestly, it's overkill, so we're going to ignore it for this build. There's no discernible difference in plugging it in when running stock, and where space is a luxury, extra cables can make or break a rear panel [Image 8].

The last piece of the puzzle is the remaining cables, and installing the final items of motherboard hardware we need. We've installed the two 8-pin EPS CPU power cables at the top left, and taken the opportunity to install the front I/O connectors as well. Even the USB 3.2 connectors are installed thanks to a sneaky 3.2 header on the bottom of the board. Given the positioning of the USB Type C header, however (again just below the 24-pin ATX power), and the lack of any cutout, we've opted not to install the USB Type C connector for the time being. HD audio also bit the bullet [Image 9].

With that sorted, it's time to move on to the CPU cooling, and boy does it come with a backplate. Check out [Image 10]—that thing is colossal for an Intel backplate. Is it needed? No, it's not a heavy water block by any means, but we appreciate the extra metal. There's just something about it that's incredibly reassuring, particularly with that etched-in diagram showing you where the threads need to go.

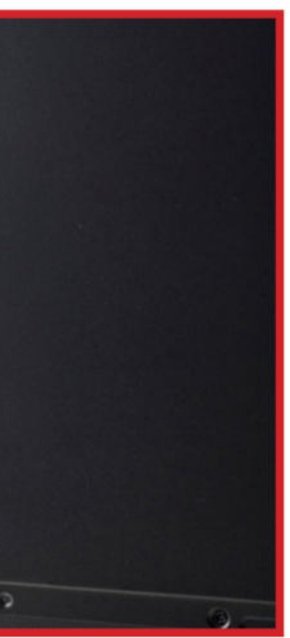

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8


9

7



10



With that done, we installed the radiator into the bottom of the case. That was a fairly painless process—it mostly involved tilting the case onto its side, then installing four screws into the bottom of the radiator through the floor. We could install the fans on top after that. Given that they're a set of the D120 daisy chain units, they're more finicky than some of the other daisy chain solutions, so first we're going to install that CPU block. There's not a lot to report on here, though. Take off the plastic cover, line up the block with the pre-installed plate with the mounts you popped in when installing that hefty backplate, then secure in place with the pre-springed thumb screws. Do this in a diagonal pattern, a little at a time by hand until you can't turn the thread, and you're all done. We ran the two slim cables up by the memory around the VRM heatsink and into that top cable management hole. There's just a daisy-chainable D-RGB cable and a single pump fan header—that's it [**Image 11**] .

ONLY FANS

Now onto those D fans. They clip together seamlessly—the only issue is that they can be a bit finicky to click in, particularly the single cable part. However, once in, we flipped them over and attached them to the radiator, making sure the cable ran out into the chassis through that cable management hole up front.

Make sure you don't preinstall the screw covers on the wrong side—they're annoying to remove. We definitely didn't do it. Also, rather more impressively, Phanteks sells a 'reversed' version of these fans, with the blades oriented the other way around in the housing. This means that the intake has the guard on it, and the exhaust is unprotected, so you can get a really clean look, and avoid that pesky aesthetic problem where the guard is facing up into your pristine-looking rig, with voltage labels and exposed wires.

One other note, because these are clipped in securely, we installed six screws: one on the top left and bottom left, and then three more in the middle fan, leaving the far right fan with just one screw in the top left corner. It's secure enough, but unfortunately, due to a minor oversight (the power supply was installed, and we didn't have a small enough screwdriver to get underneath it), we couldn't install the last screws to the right of the fan [**Image 12**].

With the AIO fans in place, we moved on to our budget offerings acting as the exhausts. These are far more traditional in their design than the D variants, but even despite the low price, still support daisy chaining RGB and fan speeds. We installed these in the roof with the included fan screws, then ran the cables around the back [**Image 13**].

With the bulk of our cabling now in, and cooling sorted, it was time to install the GPU. The Model 4 has an odd vertical bracket plate that sits over the PCIe slots that you have to remove with a thumbscrew in the rear of the PCIe slot covers. Once that's done, you can remove your traditional Philips screws to get rid of the two PCIe slot covers to install your 7900 GRE. With that done, it's simply a case of slotting the GPU into position and resecuring it in place. We then grabbed the two PCIe power cables, ran them underneath (where the front panel header cables are routed), and installed them in place, before re-attaching that vertical GPU plate in the rear [**Image 14**].

ARE WE THERE YET?

Almost, but not quite. So the GPU is in. Now, it's time to get to some more cable management done before we pop those final panels on. This time, it's those fans again. Fortunately, the vast majority of it can be daisy-chained together. Sadly, unlike some fan solutions out there, Phanteks doesn't have the dedicated software suite or bespoke cable solutions to allow for individual fan control just yet.

We've daisy-chained as much of it together as we can, certainly on the lighting front. The three D fans in the floor, and the M fans acting as exhausts, along with the pump block are running off a dRGB header on the Z790 Dark Hero.

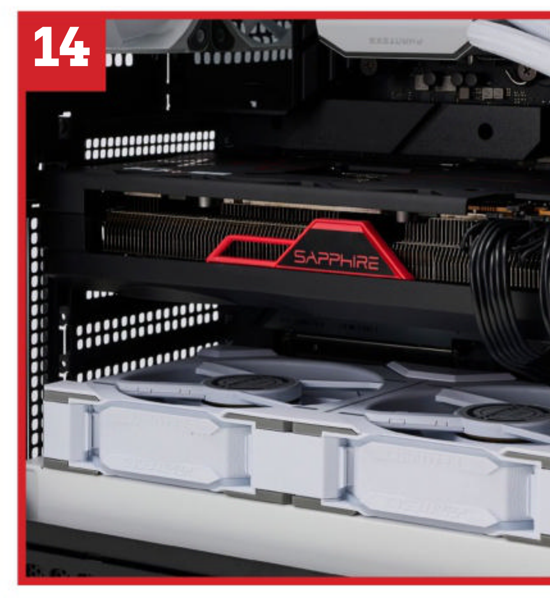
We could have run the fan speeds off a single header, but decided against it. Instead, all three M fans are running off the CPU optional header, and the three D fans are on the CPU fan, with the pump 3-pin cable on the AIO pump header on the board itself.

We've kept the side panel off while we do final checks on the system to make sure all the RGB is working correctly [**Image 15**]. We've even taken this build a step further and left it like this before grabbing a mouse, monitor and keyboard, to configure the RGB.

With all that done, it's a case of laying the case down on its side, and carefully sliding the rear/roof panel back on. The best way to do this is to lay the case down on its side, with the components side facing down on your desk. Cable management options in the rear are much better than that in the Model 8, but you've still only got a few cable tie-offs to work with, so getting the extra leverage in that old-school traditional 'lean-on-the-panel' solution works a treat here.





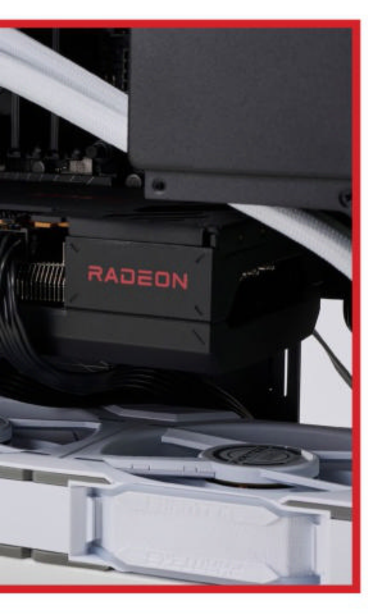






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15

THE TERRIFYING TINY TERROR

THERE YOU HAVE IT, FOLKS: one super pristine, clean, black and white, high-contrast, powerful testbed transplanted into a ridiculously small chassis, complete with all the bells and whistles you can possibly ask for, plus 6TB of delicious PCIe 4.0 and above storage. It's not pulling any punches, that's for sure.

On the whole, the chassis was a joy to work in. There's just something about it that's massively endearing. We're not sure if that's because it's not a massive manufacturer releasing one or two slightly different mass produced cases every year, but it's got spirit.

It's not perfect, let's be clear with that. airflow could be better, flexibility on how you build in it (although, of course, that is limited by the lack of internal space), and things like the rear cable management could use some channeling or extra strapping taken into consideration. That said, where it flies, it absolutely soars. The mirrored front panel, L-shaped glass, and versatile internal chassis design do wonders.

E-ATX is supported as well. We're using an ATX board here, but you can theoretically chuck an E-ATX inside. However, you'll lose access to some of the cable management grommets, which we're not sure is a good choice.

If you're worried about space, though, we can confirm that it's more than spacious. Even with that bottom AIO installed, we've managed to install an RTX 4080 Super Founder's Edition in here without a problem, and there's a good three inches of room to the right to allow for longer cards too, if you so desired. It would be real cramped, though, and internal airflow might benefit more from that rear exhaust being switched to operate as an intake to help chuck some cool air over the CPU Block and top most PCIe 5.0 SSD.

We also had some concern over the 12VHPWR cable making contact with the side panel, but there seems to be just enough space to avoid that cable-bending conundrum for the time being.

So, aside from that, is there anything we'd change about this build? Well, aside from aiming for something more premium on the GPU front, changing out those topmost M fans would certainly be on the list, or the bottom D fans. They're not bad by any length, but the color of the LEDs between the two differ by a small amount, and it's mildly annoying.

Also, to really break up the internal color monotony, if you do go with a single-color solution like we have with that bright orange on the cover, a white LED strip hidden around the roof would really help make the build's internals pop, without being too visible either. And of course, sleeved cables, but that's a *Maximum PC* given at this point.

1 The GPU sag on the bottom right of the graphics card is mildly annoying. Getting a support bracket to give this GRE a little boost would help a ton.

2 Phanteks actually sells a 'reversed' D fan solution, where the blades are oriented the other way around in the housing, so the guard protects the intake, not the exhaust. This would give these bottom fans a much cleaner look, without sacrificing performance.

3 Speaking of that bottom radiator, the color matching with it and the white fans above isn't great (the problem with matching plastic to metal) and the Phanteks logo is upside down. This is a shame, but there's not a ton we can do here.

4 Obligatory *Maximum PC* 'would look better with a custom cable kit' comment inserted here (that's a joke, but still true).

5 You can tuck a nice 24-inch white LED strip in the roof here to really make the whole build shine just that little bit more.



BENCHMARKS

Benchmark	ZERO-POINT	
Cinebench R23 Single-Core (Index)	2,031	2,094 (3%)
Cinebench R23 Multi-Core (Index)	14,545	34,869 (140%)
CrystalDisk QD32 Sequential Read (MB/s)	6,987	7,129 (2%)
CrystalDisk QD32 Sequential Write (MB/s)	6,755	6,611 (-2%)
3DMark Fire Strike Ultra (Index)	11,135	13,596 (22%)
Cyberpunk 2077 (fps)	29	72 (45%)
Cyberpunk 2077 RTX (fps)	20	15 (-25%)
Metro Exodus (fps)	46	53 (15%)
Metro Exodus RTX (fps)	34	34 (0%)
Total War: Three Kingdoms (fps)	48	51 (6%)
Core Price ($)	$1,368	$2,329 (70%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of the Hyte Y40 build from our March 2024 issue. Featuring an AMD Ryzen 5 7600X, Nvidia GeForce RTX 4070 Super, Gigabyte X670 Elite AC motherboard, 32GB of Corsair Vengeance DDR5 @ 5600 MT/s, and a 2TB Crucial T500 PCIe 4.0 M.2 SSD. All games tested at 4K "Ultra" graphics presets with DLSS and V-sync turned off and XMP for RAM speed turned on. No manual CPU overclocking. "Core Price" refers to the key components generating performance (CPU, GPU, Mobo, OS SSD, RAM), not accessories.

FALLING DOWN THE RABBIT HOLE

BUILDING THIS THING was a challenge, with lots of cable management, a ton of chassis disassembly, and more, but what was performance like? First things first, we need to caveat those sequential scores. We've already extensively tested the Kingston and Crucial T700 in these hallowed pages, and if you were after the best bang for buck, that 2TB Lexar NM790 is challenging to beat. With that in mind, we decided to test that in our sequentials instead of the two other drives.

That said, all in all, performance was pretty consistent across the board. We've compared our Model 4 build against the Stealth Hyte Y40 system we built in our March 2024 issue, so we can take a closer look at the GPUs at play here. However, it's worth mentioning just how much performance has dropped on the Core i9 14900K since its debut. Again, this is mostly down to those BIOS changes and tweaks slowly reeling the voltage and clock speeds back. A quick glance at our initial Core i9 build from way back when and you'll see CineBench R23 has dropped from 2,204 to 2,094 on single core, and 36,815 down to 34,869 in multi. That's a huge drop, and just goes to show how aggressively these boards were overclocking the chips to hit those speeds.

Still, compared to the Ryzen 5 7600X system, single core wasn't quite as potent as we'd hoped either, with the i9 only three percent ahead. Our SSD, however, performed admirably against the T500, beating it on sequential reads, and losing by a similar amount on sequential writes.

That aside, it's with the GPUs where we see far more interesting results. The 7900 GRE managed to keep up and even surpass the 4070 Super in some scenarios, beating it in *Cyberpunk* and *Metro* comfortably, but falling shy in the ray-tracing department, which is a common complaint of AMD cards. At 4K, it's certainly capable of holding its own, particularly if you lean into AMD's FSR 2.2 tech, which is great to see for a $550 card, and it's nice that AMD has that competitive edge on Nvidia, at least for the time being, although it's worth caveating the core price difference between these two.

Ultimately, the performance is pretty much where we'd expect, particularly at this price, although a lot of that is leveraged on the CPU and the motherboard driving that price up. Arguably, the 4070 Super should perform much closer if it has those extra cores to play with. Either way, if you're after a solid 1440p or entry-level 4K gaming GPU, the 7900 GRE is definitely a good pick.

EVOLUTION OF FORM FACTORS HOW DID WE GET FROM ATX TO ITX, EVERYTHING IN BETWEEN, AND BEYOND?

PC BUILDING is only possible because of consistency. The entire industry, the ecosystem, the very hardware, is dependent on that fact. From the humble transistor firing on a 1 or a 0 each and every time to DRAM producing the correct instruction to a CUDA core completing a physics calculation correctly, predictability and consistency is key. Without those, everything falls apart.

Even the componentry has to abide by a certain set of criteria, and there are a number of organizations ensuring that is the case. Most notably, the JEDEC conglomerate sets out memory standards, PCI-SIG declaring PCIe specifications for the last 20-odd years, and many others ensure that componentry meets similar specs, voltages, speeds, and dimensions. Across the board, this has led to the industry evolving rather smoothly, and stopped manufacturers from introducing all manner of proprietary and bespoke componentry, connectors, and form factors as a result.

Just take a look at the trouble Intel's been having with its 14900K, and motherboard manufacturers bypassing its recommended specifications for its chips, and you can see why these limits and specifications are important.

BUT MOTHERBOARD FORM FACTORS?

Then there's motherboard and case form factors, and oh boy, what a whole mess that is. Check out the table below to see just how many form factors are out there.

As you can see from our table, the whole motherboard form factor sizing debate has had its fair share of launches over the years, and we've seen a ton of them at *Maximum PC*, too. Perhaps unsurprisingly, IBM launched the form factor race with its XT, AT, and then Baby-AT form factors, before Intel seized the reigns in 1995 with the ATX form factor that we know and love today.

Micro-ATX followed the year after, with Mini-ITX landing in 2001, although it wouldn't become popular until the late 2000s, with the likes of Intel's Sandy Bridge architecture finally starting to bring down power demands.

Although certain form factors have stayed with us, a number of them have been one-hit wonders. EVGA debuted the HPTX form factor, measuring in at 13.6 x 15 inches in 2008, but only utilized it for two motherboards: the SR2 and SRX. The SR2 supported dual Intel Xeon processors on the LGA 1366 socket, with an

The problem with E-ATX is that as a form factor, it sort of doesn't exist, at least not consistently.

RELEVANT PC MOTHERBOARD FORM FACTORS

Year Introduced	Acronym	Expanded	Origin	Dimensions
1983	XT	Extended Technology	IBM	8.5 x 11 inches
1984	AT	Advanced Technology	IBM	12 x 11/13 inches
1987	Baby-AT	Baby Advanced Technology	IBM	8.5 x 10/13 inches
1995	ATX	Advanced Technology Extended	Intel	12 x 9.6 inches
1996	Micro-ATX	Micro Advanced Technology Extended	Intel	9.6 x 9.6 inches
1998	WTX	Workstation Technology Extended	Intel	14.0 x 16.75 inches
2001	Mini-ITX	Mini Information Technology Extended	VIA Technologies Inc	6.7 x 6.7 inches
2003	Nano-ITX	Nano Information Technology Extended	VIA Technologies Inc	4.7 x 4.7 inches
2004	BTX	Balanced Technology Extended	Intel	12.8 x 10.5 inches
2007	DTX	N/A	AMD	8.0 x 9.6 inches
2009-2010	XL-ATX	Extra Large Advanced Technology Extended	EVGA, Gigabyte, MSI	13.5/13.6 x 10.3/10.4 inches
2015	Mini-STX	Mini Socket Technology Extended	Intel	5.79 x 5.51 inches
???	E-ATX	Extended Advanced Technology Extended	Various	12 x 10/13 inches

Intel 5520 Chipset, and up to 12 sticks of triple channel DDR3, and came with seven PCIe slots, supporting up to 4-way SLI or CrossFireX. The SRX supported twin LGA2011 Intel Xeon's on the C606 chipset, with up to 12 DIMMs of quad-channel DDR3 (for up to 96GB of RAM), and sported 7-PCIe 3.0 slots, with capacity to handle 4-way SLI or CrossFireX as well.

THE PROBLEM WITH E-ATX

Then we get to E-ATX (Extended, Advanced, Technology, Extended). This is not really a form factor, as few manufacturers stick to any one set of dimensions for it. It launched as a form factor for rack mount servers measuring in at around 12 x 13 inches. However, the standoff mount locations were considerably different to that of ATX. Eventually, two variants of the form-factor emerged: one for dual-CPU systems championed by Supermicro and Asus, with bespoke mountoff locations (with a few in the same position as the ATX form factor), but with others custom positioned, requiring a specialist case. Then, a number of other manufacturers jumped on the wagon, creating larger ATX boards, and labeling them as E-ATX. Typically, these range in size, with a height of 12 inches, followed by a width of anything from 10.1 to 13 inches, depending on specification and added extras.



Standard ATX



Micro ATX



Mini ITX



Nano ITX



Pico ITX

Motherboard form factors are, let's be blunt, a mess.

CASE ADVANCEMENT

The development of cases has been fairly steady. Although the majority of case modifications you see as the halo products, or what we'd call 'glory' features (such as vertical GPUs, integrated distribution plates, and LED strips) have mainly come from the modding arena, the bulk of chassis modifications and development has arrived as hardware has advanced.

However, the biggest change-drivers have originated from a three-pronged spear of user cases. Habits have changed since the early 2000s, as the majority of the community has moved away from physical media, no longer requiring 5.25-inch drives. Then there's the shrinking of certain component elements, as 3.5-inch and even 2.5-inch storage solutions are superseded by M.2 form factor devices, and we've lost common use of SLI and CrossFire graphics solutions. More pressing than that is the end of Moore's 'law', which has led to an increase in component waste heat generation, as manufacturers look to circumvent the difficulties imposed by the limits of our current silicon lithographies.

This has led to manufacturers having more wiggle room when it comes to internal case layout, as they no longer need to accommodate for 5.25- and 3.5-inch devices. However, the flipside is that cooling and aesthetics have become increasingly dominant in this field.

Internal space and efficiency in design has increased dramatically, and cooling and glass windows have become more important. Tempered glass panels, for instance, can now be found on chassis as low as $50, while a decade ago you'd be lucky to get a perspex window for that.

Interestingly, no other company has cracked a new form factor that's better than the ones we have. ITX, ATX, and Micro-ATX, the most dominant motherboard forms, are all pre-2002. BTF looks promising, but it's more a connection standard, rather than something that will radically alter what our PCs look like.

IS BTF A FORM FACTOR?

BTF is in a way a very unique form factor. It's still early days in its lifecycle to truly understand how as a form factor it's going to develop, however. The one advantage ITX, ATX, and Micro-ATX have had is the fact that there's flexibility when it comes to the placement of the componentry on the PCB itself. Yes, the socket needs to go in the top-left center of the board, and certain elements have a rough radial area they need to be placed in, but time and time again, we've seen EPS power shift from the top-left to the top-right, the 24-pin move up and down to accommodate other elements, and USB headers, SATA headers, and more shuffle about, depending on the size, PCIe slots, and power design requirements of the board in question.

Unlike that, BTF by its nature (still technically based on the ATX sizing standard), with power connectors facing backward towards the 'rear side' of the chassis, means that case manufacturers will need to provide large cutouts for these components.

There are two angles those case manufacturers can go down when it comes to this one: abide closely to the BTF form factors requirements for where those cutouts need to be for the power connectors, or make larger cutouts. The issue is that if you make the cutouts too large, particularly as we already have chunky CPU backplate cutouts, you'll compromise the integrity and strength of the internal structure.

That might be fine on the first batch of products, but if BTF continues to gain precedent and we see it expand into more budget-friendly componentry and cases, it could lead to some rather tentative situations with structural integrity failing, particularly if a system is being transported.

For BTF to succeed, it needs to be inflexible in its design and ratified and adhered to by motherboard manufacturers. Whether that will be the case, however, is yet to be seen, particularly given the competitive nature of the partners behind it.



The BTF is technically a form factor, just not in the traditional sense.

REAL WORLD BENCHMARKING



Nate Drake explores how tools like 3DMark, Geekbench 6, UNIGINE, and Superposition reveal your device's true capabilities

IN THEORY, using tools to run 'synthetic' benchmarks is a great way to test specific components like GPUs through carefully crafted workloads. A whole industry has sprung up around this. Each developer claims to offer the best kinds of tests. Some, like Geekbench 6 or 3DMark, even have their own scoring system.

Still, winning 10,000 points and a gold star from any one benchmark doesn't necessarily mean your gaming rig will perform optimally with specific applications. This is particularly true for resource-intensive games like *Cyberpunk 2077*, and precisely what makes titles like these popular with reviewers, who like to subject devices to 'real world' benchmarks.

In this feature, we'll explore some of the most popular benchmarking software available, and discuss how to run some 'real world' tests of your own.

Geekbench 6

POSITIVES
- Simulates real world scenarios
- Scores Single Core/Multi-core Performance separately
- Mobile version

NEGATIVES
- Not ideal for benchmarking servers
- Benchmarks aren't comparable to other Geekbench versions
- Free users forced to upload results

GEEKBENCH is one of the best-known benchmarking platforms, and a favorite of hardware review sites.

Speaking to Ars Technica in 2023, Geekbench creator John Pool explained the inspiration for creating a new series of benchmarks came in 2005 when he purchased a Power Mac G5. Dissatisfied with existing tests, which consisted of running arithmetical operations on small amounts of data, Poole developed his own.

When it comes to scoring, Geekbench uses a baseline of 2500 based on benchmarks run on a Dell Precision 3460 with an Intel Core i7-12700. A higher score indicates better performance. According to Geekbench's documentation, theoretically this means that if one device has double the score of another, it will perform twice as well.

Geekbench 6 provides two composite scores of both single-core and multi-core performance. These are calculated using a weighted average of the subsection scores. In turn, these scores are worked out through using the geometric mean of workloads contained in that subsection.

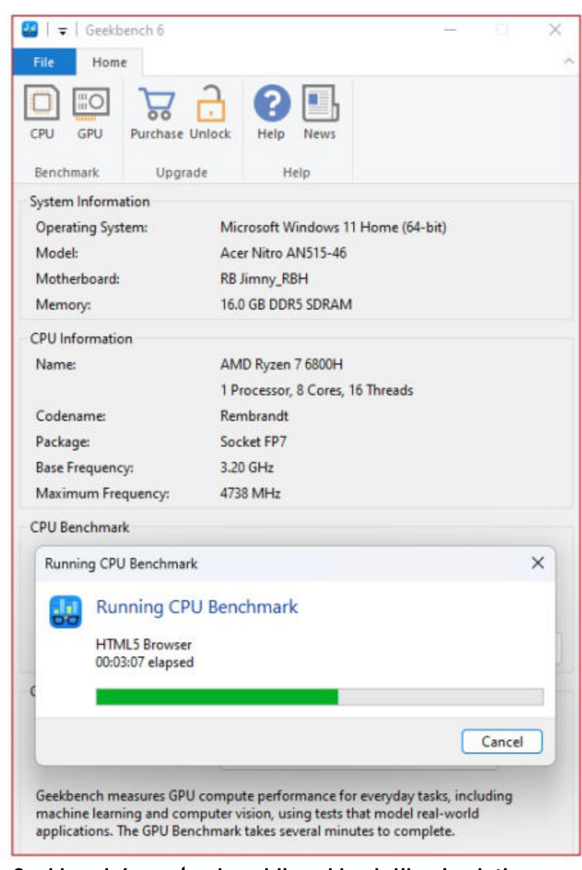
Although this sounds quite involved, the results are easy to interpret, and it's relatively simple to compare the performance of your device to others. The only downside is that if you choose to use the free version of Geekbench 6, your results will automatically be uploaded to the main website.

On the plus side, Geekbench is a truly cross-platform application. Mobile versions are available, and it can even run on Linux, albeit from the command line.

If you're running Windows, once the software has been downloaded from www.geekbench.com and installed, it will automatically display key information about your OS and hardware. At this stage, all you need to do is click 'Run CPU Benchmark'.

Unlike many other benchmarking apps, there's no graphics rich video or mini-game to play, but Geekbench offers some of the very best workloads for real world benchmarking.

The software will first attempt to run 'productivity' workloads. This includes a test of how your device handles file compression, using a 75 MB Ruby source archive with LZ4 and ZSTD compression codecs. There's also a 'Navigation' workload that generates directions over 24 routes in two different locations via OpenStreetMap.



Geekbench 6 runs 'real world' workloads like simulating opening multiple web pages.

Special mention should also go to the HTML5 workload, which uses a 'headless' browser to simulate typical internet activity by opening, parsing, and rendering texts for various web pages like Instagram and Wikipedia. There's also a 'PDF render' workload, which uses park maps from the American National Park service and a 'Photo Library' workload to categorize and tag images based on objects they contain.

Geekbench next runs a series of 'Developer Workloads' on your device. These include using Clang to compile the Lua interpreter to simulate programmers building their own code. The 'Text Processing' workload uses Python and C++ to load multiple files, then parses their contents using regular expressions. It also stores metadata in an SQLite database, then exports the content to a different format.

The 'machine learning' workloads involve detecting and highlighting objects in multiple photos. Geekbench also measures CPU performance by separating the background and foreground in a video stream.

The final set of CPU workloads focus on how your device manages editing and synthesis of images. These again simulate real world tasks like removing objects from images and filling the gap left behind, as well as correcting the horizon in crooked photos.

Other workloads include applying filters to images to improve their appearance, blending six photos to create a single HDR (High Dynamic Range) image, and using a custom ray tracer to render the Blender BMW Scene.

Upon completion of CPU benchmarks in the free version of Geekbench 6, your browser will automatically open and display the uploaded scores for both single-core and multi-core performance.

By default, these scores aren't shown in relation to anything else, but you can use the 'search' feature at the top right to search for your specific CPU to check other uploaded scores. You can also visit https://browser.geekbench.comprocessor-benchmarks to view current CPU scores from highest to lowest.

UNIGINE Superposition Benchmark

POSITIVES
- Useful for measuring overclocking
- GPU temperature/clock monitoring
- Mini-game

NEGATIVES
- Limited customization in Basic version
- Can crash if VRAM limit reached
- 'Leaderboards' submissions denied for modified preset

IF THE NAME of developers UNIGINE sounds familiar to readers, it's because they're the authors of a number of other excellent benchmarking tools, such as Heaven, which displays a jaw-dropping representation of a steampunk village guarded by an ornate dragon statue.

On downloading the 1.2GB installer for this benchmarking software from https://benchmark.unigine.com/superposition, setup offers three options. This is where we discovered that the 'Basic' version of Superposition supports running 'Virtual Reality' benchmarks for Oculus and SteamVR HMDs (Head-Mounted displays).

Superposition also displays a helpful bar at the bottom indicating how much VRAM is required for the next round of benchmarks. If you try to exceed the available virtual memory, the program will display a warning and suggest you lower the settings or use another 'preset'. The default preset is '1080p medium'.

Readers may take exception to the fact that we've noted this as a disadvantage, given that any program can crash your device if it has insufficient virtual memory. Still, we feel that rather than display a warning, it would make more sense for Superposition to default to the least demanding preset (720p Low), then allow users to adjust settings upwards accordingly, eg. the '8K Optimized' preset requires 6241MB of VRAM by default.

You can further customize your benchmarks by selecting 'Custom'. From here, you can switch the Graphics API between DirectX and OpenGL. You can also toggle fullscreen, change the video resolution, and adjust quality for shaders/textures. Bear in mind, however, that if you create a custom preset, you cannot upload your results to UNIGINE's Leaderboards.

Once the settings are to your liking, the fun begins. The standard benchmark in Superposition works by displaying a detailed video using SSRTGI (Screen-Space Ray-Traced Global Illumination) dynamic lighting technology.

The clip in question is a 1950s classroom filled with the dangerous inventions of a seemingly mad Professor. The experience is akin to shooting a film scene in a single take. As the camera pans and zooms, Superposition will display key stats at the top right. These include GPU clock speed, temperature, and 'utilization'.

As the scene progresses, the camera goes from simply displaying high-res scientific equipment to having objects levitate and move around the room, which in our tests caused a big spike in GPU load.

Other useful information includes the minimum, maximum, and average FPS (frames per second), as well as the current scene number: 17 in total.

It's clear why Superposition is a favorite of overclockers. Displaying information in a standardized way makes it easy to measure the effects of modifications like increasing the GPU power limit.

Once the video finishes playing, Superposition will display a summary of your benchmark settings, as well as your system configuration. Your overall score will also be displayed, along with key stats like the minimum and maximum FPS, GPU temperature, and utilization.

You can also click 'Compare Results Online' to view the UNIGINE Leaderboards. However, this won't display your results in relation to others. Make sure you select the correct 'preset' to be sure you're looking at the right score set. You can also use the search box to enter the make and model of your hardware.

Superposition 'Advanced' does, however, support posting your results on the Leaderboards, as well as looped stress testing to check hardware stability. If you don't want to pay $20 for this, you can get an approximate idea of how your hardware would handle graphics-intensive titles by selecting the 'Game' option from Superposition.

Before playing, choose a 'Preset' that your system can handle or 'Custom' graphics settings to your needs, then choose 'RUN'. Doing so will transport you to the same lone scientist's classroom/lab but this time you'll be able to navigate the room and interact with over 900 objects.

The controls follow the traditional WASD format, with the mouse used to change the view. Objects with which you can interact have a helpful tag explaining what you can do, eg. 'Take'.

The main advantage of interacting with Superposition in this way is that it can give you a clearer idea of how your system performs when you're carrying out in-game activities such as moving from one area to another. Key information like FPS, GPU clock speed, temperature, and utilization is still displayed at the top right.

Unlike the regular benchmark, there's no set ending, nor will you see an average of all results during gameplay, but it's a way to see how your GPU performs under specific circumstances. For instance, to push the graphics performance to its extreme, you can activate the 'gravity vortex' at the far end of the lab.



Superposition displays your GPU score, but you'll need to upgrade to upload it.



POSITIVES
- Many different types of benchmarks
- Transparent scoring system
- Stress tests available

NEGATIVES
- Limited free demos
- Free versions must be installed via Steam
- Scores only apply to specific 3DMark versions

LIKE GEEKBENCH, 3DMark is an extremely popular benchmarking platform. Its scoring system is also similar in that higher marks mean better performance.

There are 'Advanced' and 'Enterprise' editions for $34.99 (one-off) and $1,695 (per year), respectively. These contain the most comprehensive sets of tools, as well as features like custom benchmark settings and game performance estimates. 3DMark also offers free demos of three tools. In order to access these, though, you'll need to have a Steam account to search for and install the '3D Mark Demo' via the Steam Store.

Time Spy is used for testing DirectX 12, so will only work with Windows 10 and 11 platforms. The tests are run at 2560 x 1440 resolution. The demo version consists of two graphics tests and one CPU test, which are run in that order.

According to 3DMark, the first graphics test consists of a great deal of transparent content, particle shadows, and tesselation. The second features ray-marched volumetric illumination, with hundreds of lights and small particles.

During all three tests, the current frame, FPS, and video duration are displayed at the bottom of the screen. You'll then see an overall score, as well as one for your GPU and CPU. Unlike certain popular benchmarking platforms, 3DMark gives you an idea of where your hardware stands by displaying both the average and best score for each tool.



Time Spy (pictured) runs two GPU benchmarks and one CPU benchmark.

Although the 'Basic' edition doesn't allow you to estimate game performance, you can scroll down further to see a detailed view of system performance. This includes the FPS for individual tests as well as graphs displaying the same, along with GPU temperature and load.

The final section contains the 'Run Details'. This is an extremely well-laid out comparison between the performance of your device and others, such as a budget gaming PC or gaming laptop. Your device is ranked along with a percentage result of its performance—for instance, our Acer Nitro laptop only performed better than 20 percent of all results.

If you have a less modern device, the 3D Mark demo also includes 'Fire Strike' for DirectX 11 benchmarking, as well as 'Night Raid'—a DirectX12 benchmarking tool for devices with integrated graphics.

If you choose to upgrade to the 'Advanced' version, you can access the 'Extreme' edition of both Time Spy and Fire Strike. These raise the rendering resolution to 3840 × 2160 (4K UHD).

SSD BENCHMARKS

While testing your CPU, RAM, and GPU performance is vital, it's easy to overlook your storage.

Recent years have seen a decline in the sale of old-style magnetic HDDs in favor of SSDs (Solid State Drives), which are capable of much faster read and write speeds.

One of the most popular SSD-testing tools is CrystalDiskMark, an open-source tool designed for Windows. Based on Microsoft's Diskspd, this can simulate read/write operations in both sequential and random positions with various numbers of both queues and threads.

Head to https://crystalmark.info/en/download/#CrystalDiskMark to view the downloads. As readers will see, the 'Shizuku' and 'Kurei Kei' editions are 200MB and 120MB respectively, possibly due to the themes containing scantily clad anime girls. Fortunately, the 'standard' version is cleaner, containing a basic UI and is just 5MB.

CrystalDiskMark runs five tests on the main hard drive. The first two use sequential 8 MiB blocks of data, while the remainder use 4 KiB blocks.

Use Ctrl + Q to fine tune these settings, or access other batteries of tests via the 'Profile' menu. The options include 'Real World Performance', which focuses more on random data blocks.

In the 'Theme' menu, you can choose from a variety of palettes. You can also enlarge the window— the default size makes it difficult to see individual numbers.

There's no option to upload the results to CrystalDiskMark's website, nor does the tool indicate that your SSD is performing within acceptable parameters.

You can, however, install it via the main website. This provides detailed information of SSD functions, as well as the temperature and the drive's overall health.

HWMonitor

POSITIVES

- **Very small install footprint**
- **Clear information**
- **Free version has excellent features**

NEGATIVES

- **Not designed specifically for benchmarking**
- **Hard to compare stats with other devices**
- **Takes time to load**

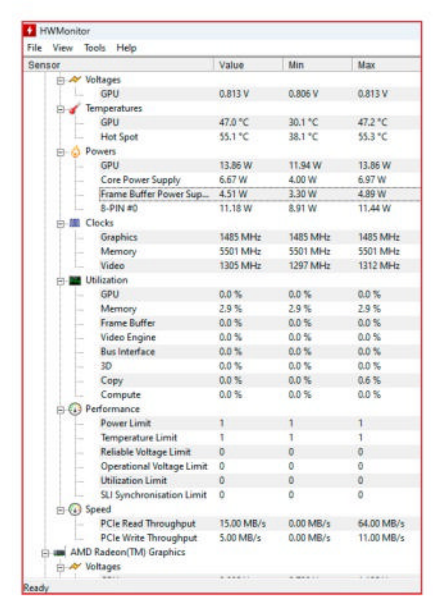
HWMONITOR is developed by CPUID, the same people behind the excellent system profiling/monitoring application CPU-Z. It's available as both a free and a 'Pro' edition, though as we've noted, the free edition is likely to offer all the features required to monitor your system.

Admittedly, HWMonitor stands out, as it's not specifically designed for benchmarking. There's no clickable button to stress-test your hardware, no scoring system, and no automatic way to compare what you see with other devices.

However, if you visit www.cpuid.com/downloads/hwmonitor, you will find a free utility for viewing key information like core temperature, power consumption, GPU & CPU utilization, and so on.

This is what makes HWMonitor such a popular tool with overclockers, as if your device is heating and/or shutting down unexpectedly, it can give you some insight into why this might be happening.

The installer itself is only around 1.5MB and the interface is very simplistic, so it's unlikely that HWMonitor itself will contribute significantly to CPU/GPU load. You'll gather the most meaningful data by running it at the same time as one of the other benchmarking tools listed in this feature, ideally in windowed mode, so you can monitor your system stats in real time.



Use HWMonitor when running benchmarks to monitor key system performance indicators.

Before running any benchmarks in HWMonitor, open the 'View' menu and choose 'Clear Min/Max' to make sure the results only apply to this specific test. From here, you can also enable the 'dark theme'.

When it comes to checking temperatures, HWMonitor defaults to listing these in Centigrade. If you prefer to use Fahrenheit, go to 'Tools' > 'Options' to switch. From here, you can also limit 'utilization' to 100 percent, though if you're overclocking, you may prefer to leave it.

If you need to share your results with others, go to 'File' > 'Save Monitoring Data', or hold Ctrl + S to store the stats as a plain text file.

BATTERY BENCHMARKS

There used to be various free dedicated programs for testing battery endurance. One example was PCMark10 (aka PowerMark), but sadly this is no longer available.

If you're running Windows 10 or 11, you can use the OS's internal diagnostics. Type 'cmd' into the search bar to open the command prompt, then run powercfg /batteryreport. This will generate an html battery report, which will be saved to your home folder.

Open the html file in your browser, and you'll see a record of your active battery usage over the past few days. The 'Installed Batteries' section lists the 'design capacity'—the maximum charge the battery could hold when brand new. Contrast with the 'full charge' capacity to determine how much charge the battery can hold.

Scroll down to the 'Recent Uses' section to view power states over the last three days. This can give you an insight into how quickly the battery is draining. By scrolling down to the 'Battery Usage' section, you can see the duration your device was unplugged, as well as energy drain during that time.

Theoretically, you can use this to calculate the battery efficiency, but the report has a dedicated 'battery life estimates' section. Here, you can view an aggregate of all the battery data since Windows was first installed.

This data will change over time. Even small changes can make a difference—for instance, Microsoft Edge consumes less power than other mainstream browsers, like Chrome and Firefox. This is why independent review sites like TechRadar also test the battery capacity of laptops by playing a high definition video in a continuous loop.

To go down this route, try to find an HD video of sufficient length, and decide on a media player. We favor VLC (https://get.videolan.org). Not only is it free and open-source, it can also make use of DirectX Video Acceleration (DXVA) for hardware acceleration. Tests run by Microsoft Program Manager Pierre LaGarde found that a GPU-enabled VLC is 70 percent more energy efficient than using the CPU.

To run a fair test, you need to configure your battery settings. Enter 'Power and Battery' into the Windows search bar to open the relevant window. By default, Windows 11 will hibernate when the battery reaches a 'Critical' level of two percent. To change, this enter 'Edit Power Plan' into the search bar to open the relevant section of the Control Panel. Choose 'Change advanced power settings'. Expand 'Battery' > 'Critical Battery Level' and change this to 0 percent. You can also change 'Reserve Battery Level' to 0 percent, if you wish.

Once you've clicked 'Apply', we recommend setting system brightness and volume to an arbitrary level, eg. 50 percent. Close all other apps and disconnect any external devices. When you open the video in VLC, before starting your stopwatch, click the 'loop' button at the bottom to play it continuously.

DIY Benchmarking

POSITIVES

- **No third-party programs required**
- **Easy to implement**
- **Based on 'real' performance**

NEGATIVES

- **Stress tests are harder**
- **Less customizable tests**
- **Can take more time**

THE BENCHMARKING tools that we've reviewed so far are the best ones we found for simulating 'real world' performance of devices. For instance, Geekbench 6 actually uses a headless browser to simulate web browsing activities.

Additionally, software like 3DMark's Time Spy carefully measures metrics while rednering footage similar to what you would find in a graphically rich videogame.

Still, it only takes a quick search on forums like the /r/overclockers subreddit in order to see that users are often baffled by the results. The chief complaints are that their device will pass popular benchmarks with flying colors, but games will still not perform to a sufficient standard.

This is an excellent demonstration of the old English adage, 'The proof of the pudding is in the eating.' In other words, the quality of your hardware is best judged on direct experience.

Sometimes, this is easier to resolve, as certain games, like *Cyberpunk 2077*, contain internal benchmarking tools, which you can use to assess system performance, particularly in light of any modifications you've made.

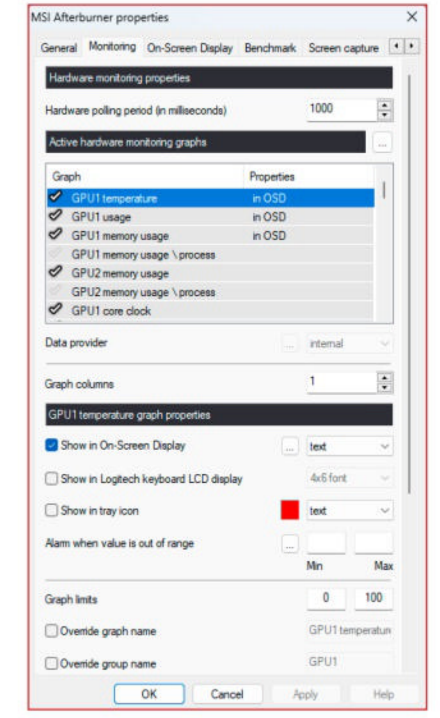
If you aren't fortunate enough to be using a game that supports benchmarking and configuration, you can still perform your own tests by installing MSI Afterburner (www.msi.com/Landing/afterburner).

Afterburner is best known as a graphics overclocking utility. However, during setup, you will be prompted to install RTSS (RivaTuner Statistics Server), a performance monitor for graphics cards and APIs. Once the installation is complete, open MSI and click the settings icon on the left. Use the 'General' tab to select your principal GPU from the top drop-down menu. Next, click into the 'Monitoring' tab.

Hover your mouse over the 'Active hardware monitoring graphs', and read through the tooltip. As you will learn, you can click the tick mark next to each graph name, eg. 'CPU1 Clock', then check the box marked 'Show in On-Screen Display' to have it appear in-game. Do this for other key data like GPU temperature and CPU usage.

The default polling period is one second, but you can adjust this from the top of the window if you wish. Click 'Apply' to save changes. We noted during our research for this article that MSI can take a few moments to do this.

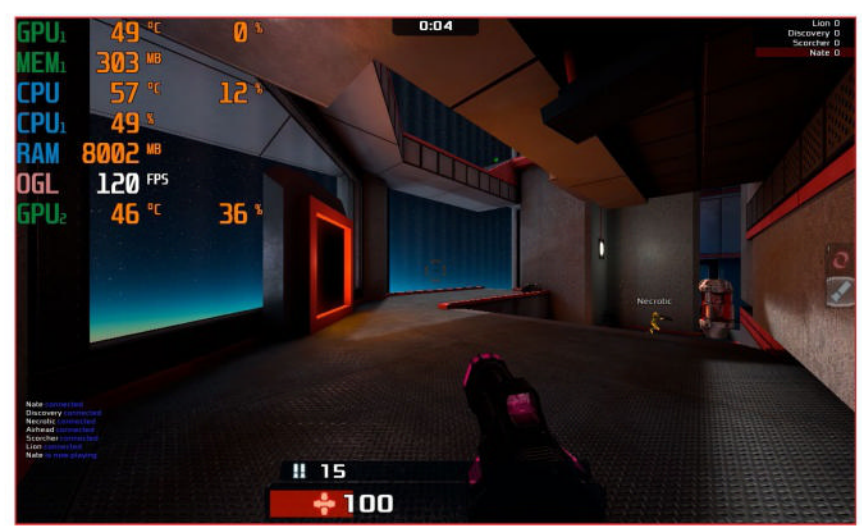
Next, find the RTSS launcher among the 'hidden icons' at the bottom right of your desktop. First, adjust the 'On-Screen Display Zoom' slider to make sure the text is large enough. Click and drag your mouse on the '60' in the bottom box to set where the game data will appear on screen. You can also click into the 'On-Screen Display palette' to adjust the text color. By default, the stats appear as a transparent overlay in-game, but you can enable 'On-Screen Display Fill' if you wish.



Click the tick mark next to the performance indicators you want to see.

RTSS cautions that some anti-cheat systems in games may detect the kind of application code hooking/on-screen display required for benchmarking, and falsely assume that you're playing unfairly. If this happens then we recommend enabling 'Stealth Mode', which supposedly makes RTSS harder to detect. Once you've done this, it's simply a matter of firing up your chosen game to view your chosen stats.

Unfortunately, MSI is focused on graphics and CPU performance, so there's no way to monitor hard drive read/write speeds while you're playing. However, at the very least, you can identify actions and areas in-game that subject your CPU, RAM, and GPU to the most usage.



By default, RTSS displays key performance monitors in a transparent overlay in-game.

BEST FREE SOFTWARE

To Stay 100% Private Online

Don't compromise your privacy by using the same old tools. *Robert Irvine* reveals the best new ways to block web trackers, protect your data, and stay anonymous

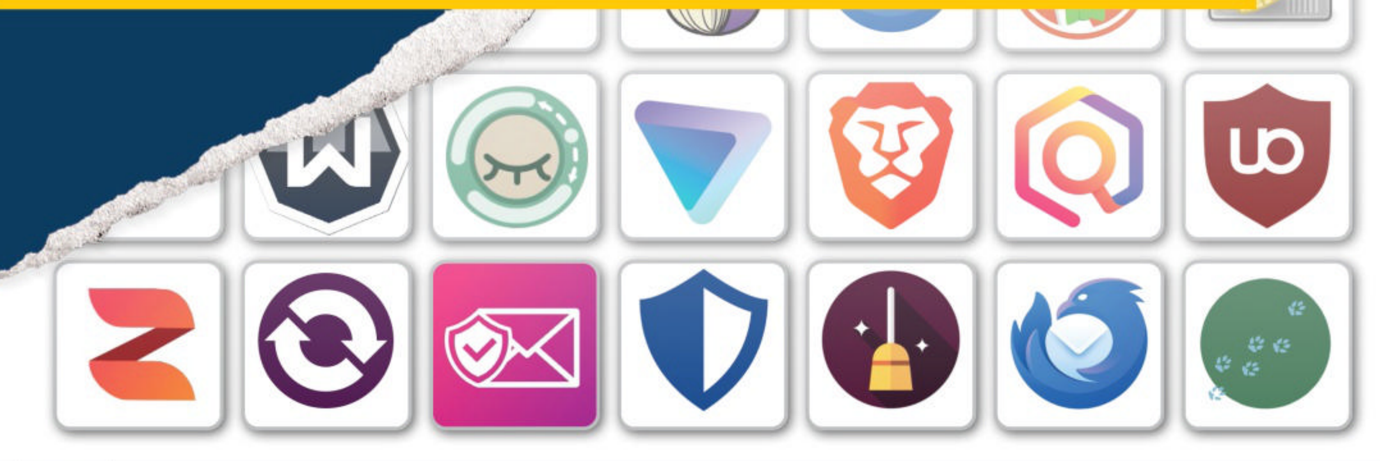
Privacy is such an important aspect of our online lives that it's often exploited to promote software that's not private. 'Keep your privacy under control', says the download page for Chrome, despite Google being court-ordered to destroy user data it collected through the browser's Incognito mode (tinyurl.com/ysb8xpcv). 'Maintain your online privacy' promises CCleaner, whose privacy policy states that it 'collects personal data in order to personalize ads for you' (tinyurl.com/58kskj9f).

Popular though these programs are, they undermine your privacy rather than boost it, while some lesser-known tools are more trustworthy. Rather than collect and share information about your web activities, they protect you from companies who engage in intrusive practices by blocking trackers, disguising your identity, and letting you easily delete your private data.

In this feature, we reveal the best secret software for staying anonymous online, as well as highlighting new features and hidden privacy settings in programs you may already use.

Unlike Chrome's Incognito mode, which doesn't stop sites collecting your data—as Google now admits—these tools work exactly as promised, allowing you to browse the web discreetly without being spied on.

We've chosen a mix of free Windows software, browser extensions, and mobile apps to keep you 100 percent private on every device.



BLOCK ALL TOOLS THAT TRACK YOU

Block more trackers in web pages

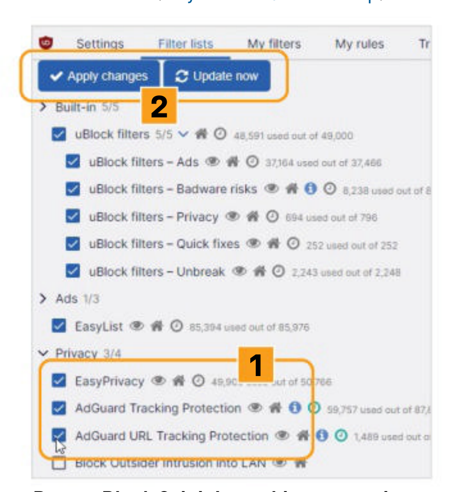


All the main web browsers now include tracking protection, though some (Brave and Firefox) do a better job than others (Chrome and Edge) through their 'strict' or 'aggressive' settings. However, to stay completely private online by blocking every hidden tracker, you need uBlock Origin (ublockorigin.com).

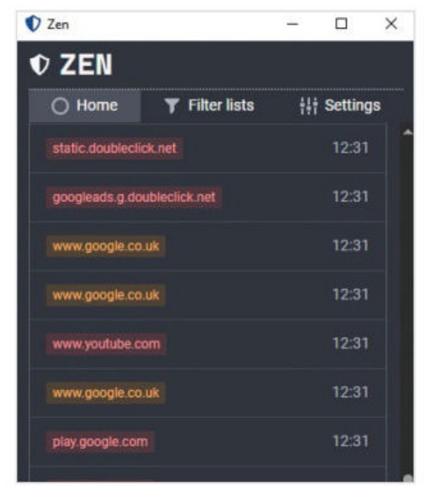
This extension now has around 55 million users worldwide, but it's still not as well known as inferior rivals such as AdBlock and Adblock Plus. Even if you already use uBlock Origin to block ads, trackers, and annoyances, you may not realize that it has additional options for blocking further privacy risks.

Right-click the add-on's toolbar button, choose Options, and click the 'Filter lists' tab. Click the arrow next to Privacy and tick the AdGuard Tracking Protection and AdGuard URL Tracking Protection boxes—as well as Easy Privacy, if it isn't enabled (1 in our screenshot below). These augment uBlock Origin's own filters with rules from freemium service AdGuard to provide comprehensive, and constantly updated protection against the latest trackers—including those hidden in web addresses. Click 'Apply changes', then 'Update now' 2.

Annoyingly, Google's new Manifest V3 system, which it's introducing this year, will limit content blockers to using 30,000 filtering rules—uBlock Origin currently uses around 300,000—which will make them less effective at blocking ads and trackers. To beat this restriction, uBlock Origin has created a Lite version for Manifest V3 (tinyurl.com/mrx2udcp) that



Boost uBlock Origin's tracking protection using additional filters from AdGuard.



Zen sets up a proxy to block tracking requests in Windows software.

lets you configure its filters on a site-by-site basis by choosing from Basic, Optimal, or Complete filtering modes.

Block trackers in Windows software



Tools such as uBlock Origin make it easy to block trackers in your browser, but it's more difficult to avoid them in other software on your PC. Many programs now include tracking elements that connect to the internet in the background to share details of your activities with developers, advertisers, and data brokers—and potentially criminals.

You can block these using a new open-source tool called Zen (tinyurl.com/ycfrfd2p—go to the Downloads section under the program description), not related to Zen Internet. This free ad-blocker and privacy guard sets up a proxy that intercepts tracking requests from internet servers and blocks any containing ads, tracking scripts, malware, and other unwanted content. By working at a system level, Zen protects your PC against threats that browser extensions miss, such as trackers embedded in Windows software and system components.

Download and run either the x64 installer or portable version of Zen, clicking 'More info' then 'Run anyway' when you see the Microsoft Defender SmartScreen warning—it's safe to use. When you first open the program, click Start then Yes to install its root certificate, which allows it to check and modify HTTPS requests. This certificate is privately generated and stored on your PC.

Once this is done, Zen will start showing blocked requests on its Home tab. To boost its protection, click the 'Filter lists' tab and switch on 'Peter Lowe's Ad and tracking server list'—further filters can be enabled in the drop-down menu. If you have trouble loading a particular website or program, click Stop to disconnect from the proxy.

Although Zen isn't as powerful as paid-for solutions, such as AdGuard's Windows app (tinyurl.com/2wdc2rkv), it's easy to use, and you don't need to sign up for an account.

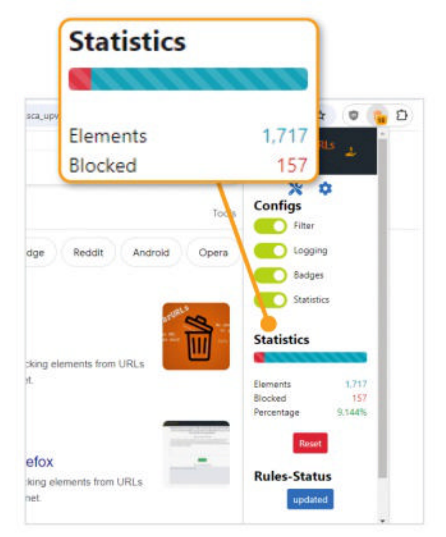
Remove tracking elements from URLs



Many URLs on websites—including Google search results, Amazon product pages, and social-media posts—contain extra code after the main web address. This is usually for analytics purposes, to tell site owners when you clicked the link, the country you're browsing from and the device you're using, but the code can also be used to track you around the web.

To stop this happening, install the extension ClearURLs in your Chromium (tinyurl.com/4kws77pz) or Firefox browser (tinyurl.com/22vn9hcn). This protects your privacy by removing tracking elements from URLs, and letting you click through to pages without being redirected through a third-party service.

You can see how many elements the extension has blocked by clicking its toolbar button and checking the Statistics



ClearURLs removes tracking code from URLs, including Google search results.

section in the information panel. If ClearURLs prevents some sites from loading properly, click the Settings cog and switch off 'Allow domain blocking'.

Brave and Firefox let you remove tracking elements when you copy links. In the former, right-click the link and choose 'Copy clean link'; in the latter, select Copy Link Without Site Tracking.

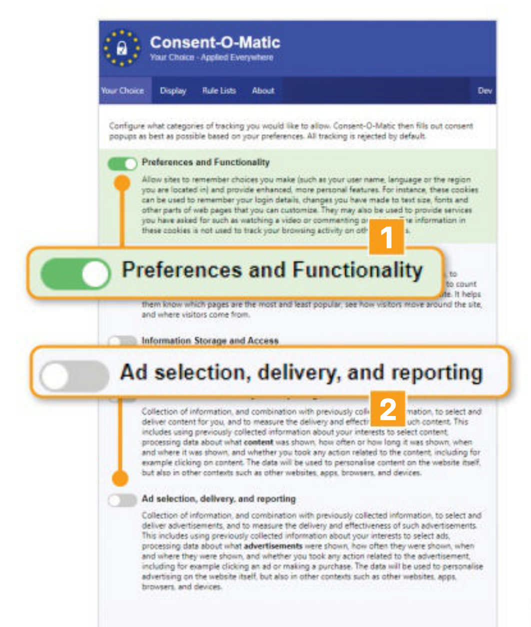
Don't get tricked by cookie consent pop-ups



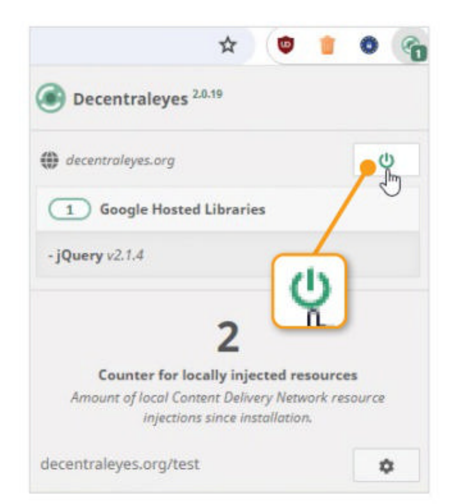
Cookie-consent pop-ups are supposed to give you more control over the data websites collect about you, but are often so confusing that you end up agreeing to be tracked. The popular extension I Don't Care About Cookies solves the annoyance of these pop-ups by hiding them, but it also allows sites to install cookies.

Consent-O-Matic is a lesser-known but more private alternative, which rejects all cookies by default and hides consent banners. Available for Chromium browsers (tinyurl.com/tdwkdus8), Firefox (tinyurl.com/ysp7hkc7), and Safari on iOS (tinyurl.com/22h62tr5), it lets you configure its settings to permit essential cookies while blocking tracking ones.

Click its toolbar button, choose More Add-On Settings, and on the Your Choice tab, select the categories of cookies you're happy to allow. For example, 'Preferences and Functionality' 1 enables sites to store data such as your login details and personalization settings, while 'Ad selection, delivery, and reporting' 2 gives them permission to track you.



Consent-O-Matic rejects tracking cookies while allowing essential ones.



Decentraleyes replaces web content that could track you with its own files.

You can add rules to Consent-O-Matic to improve its detection and blocking. Click the Rule Lists tab and copy the URL of a rule list into the Add List box—get the one used by I Don't Care About Cookies from tinyurl.com/7xwvjdan.

Stop content-delivery networks tracking you



Lots of websites rely on third-party services to provide some content, including images, videos, and fonts. Known as content-delivery networks (CDNs), these services help speed up page-loading times, but they're also able to track you. This is because once you've viewed their content, they can follow you to the next site that uses their network.

Blocking CDNs may cause sites to break, but you can stop them tracking you by installing Decentraleyes in your Chromium (tinyurl.com/myc2adf9) or Firefox browser (tinyurl.com/3r74rh3n). This cuts out the CDN middle man by tricking websites into loading its own, locally stored files to display content. By doing so, Decentraleyes protects your privacy without affecting browsing—you can see how many resources it's replaced on pages by clicking its toolbar button.

It works in tandem with content blockers such as uBlock Origin, and without you needing to configure its settings. If you have trouble loading a site, click the power button to disable the add-on's protection.

Block hidden trackers in mobile apps

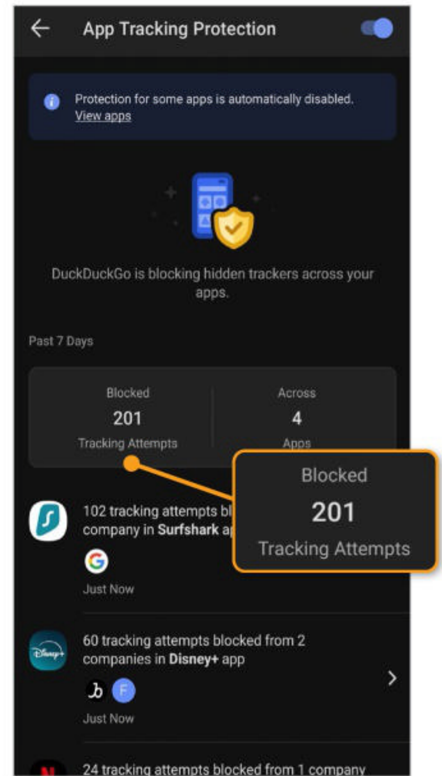


Some trackers embedded in mobile apps collect data about your activities to share with advertisers and other companies, not only within the apps themselves, but in other apps installed on your phone or tablet. This is why you often see ads and sponsored content relating to things you've looked at in one app appearing in a completely different tool.

The DuckDuckGo Private Browser for Android (tinyurl.com/yeyx6rzz) prevents this from happening using its App Tracking Protection feature. As well as blocking hidden trackers in sites you visit, it refuses tracking requests in other apps on your Android device. This stops them collecting data about you while allowing the permissions they require to work.

To activate this, tap the three-dot menu in DuckDuckGo Private Browser, select Settings, and enable App Tracking Protection. Tap 'OK' to allow DuckDuckGo to set up a VPN on your device. This allows the browser to block trackers at a network level. DuckDuckGo will tell you how many tracking attempts it's blocked in apps in the past seven days, and the apps and tracking companies responsible.

The iOS browser (tinyurl.com/4y58ua3h) doesn't include this feature, but your iOS device has its own setting for blocking app tracking. Select 'Privacy & Security' in the Settings app, tap Tracking, and switch off 'Allow Apps to Request to Track'. All new app tracking requests will be automatically denied.



DuckDuckGo's Android browser stops apps tracking what you do in other apps.

MAKE YOURSELF INVISIBLE ONLINE

Make websites forget you visited them



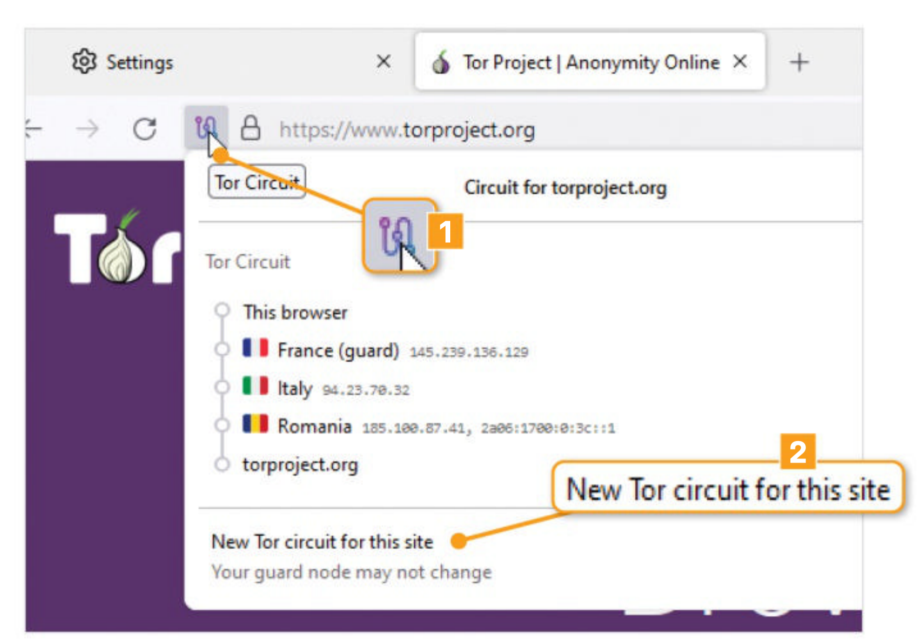
It's no secret that the incognito or private mode in your browser doesn't keep you anywhere near anonymous online—as Google was recently forced to clarify. But Brave (www.brave.com) now has a secret feature called 'Forget by Default', which goes further than standard private-browsing modes by preventing websites from identifying you.

'Forget by Default' works by logging you out of a site and deleting all its cookies and other stored data when you close its browser tab. This means that next time you visit that site, it won't automatically recognize you, and tailor its content—and ads—accordingly.

To access the feature, click the Shields (lion head) button on Brave's toolbar, and switch on the option, 'Forget me when I close this site' (see screenshot below). This will sign you out and delete all cookies and other data as soon as you close the current tab.

To enable 'Forget by Default' for every site you visit, click Brave's three-line menu button, choose Settings, then Shields, and switch on 'Forget me when I close this site'. You can disable the option on specific sites to stop them logging you out by clicking the Shields button and switching it off.

Visit brave://settings/content/all to confirm that 'Forget by Default' is wiping stored data when you leave a site (some unremovable cookies may remain).



Tor Browser routes your internet connection through a series of global relays.

Browse the web anonymously using Tor



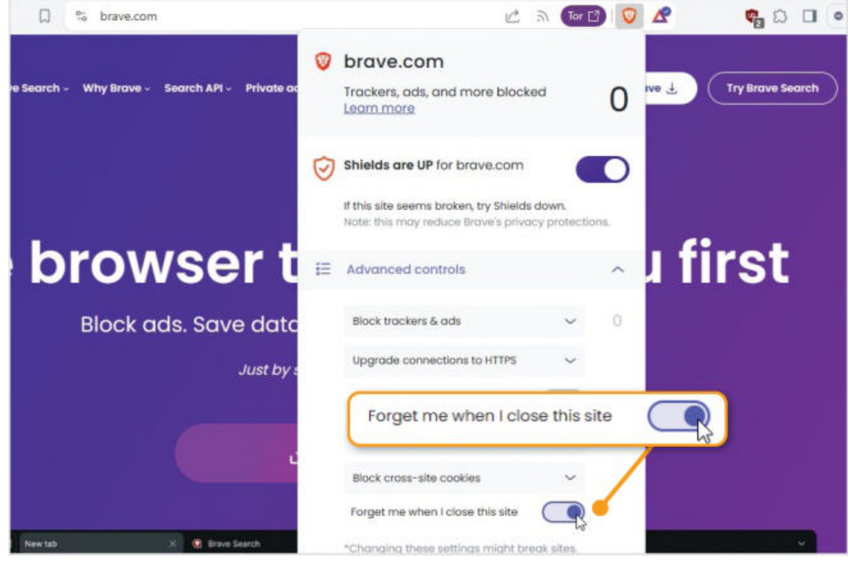
Brave also has a private-browsing mode that uses the Tor network to stop websites tracking and identifying you. It recently improved this mode by automatically loading the onion address of sites when available, and by redirecting you to Tor when you try to visit an onion address in standard-browsing mode. However, to stay completely anonymous online, you should use the dedicated Tor Browser (torproject.org), which works in permanent private-browsing mode.

Tor Browser redirects your internet connection through an encrypted circuit of 'relays' around the world, which prevents websites, hackers, and other snoopers from seeing where you are and what you do online. It automatically deletes cookies, site data, and browsing history when you close it, leaving no trace of your activities, and offers a choice of security levels to disable web features that compromise your anonymity.

Tor simplified the browser's circuit system to make it easier to check which relays (also called nodes) your connection is being diverted through to disguise your IP address. Click the Tor Circuit (squiggly line) icon to the left of the address bar (1 in our screenshot above) to view the nodes' locations and IP addresses. If you suspect your anonymity has been compromised, perhaps because you've entered personal information on a website, click 'New Tor circuit for this site' 2 to be redirected through a new series of relays.

Tor recently introduced a powerful privacy feature called WebTunnel, which stops anyone—including your ISP—knowing that you're using its encrypted network.

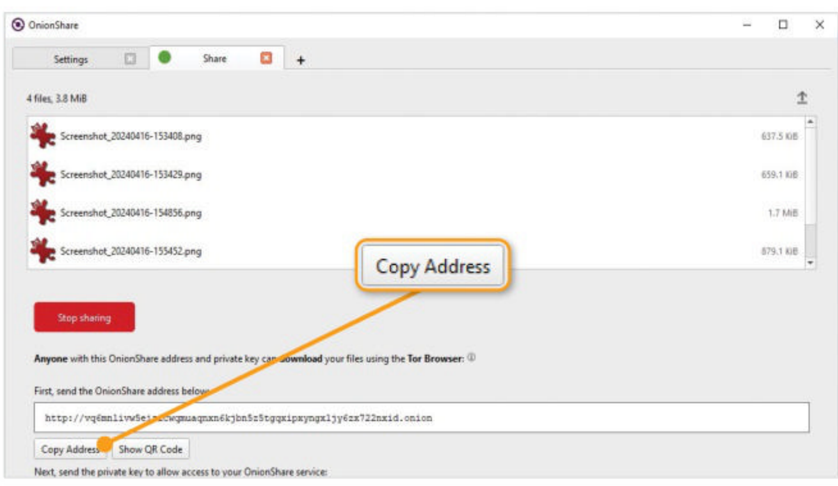
Although Tor Browser lets you access the so-called dark web, you need to enter 56-character onion addresses to visit such sites, so you won't accidentally stumble across anything illegal. Besides,



Use Brave's new 'Forget by Default' option to stop websites identifying you.

many reputable websites, including BBC News and Amnesty International, have onion versions to help visitors beat censorship and surveillance. The main drawback is that loading standard sites can be slow—especially at the browser's Safest security level.

Tor Browser also has an Android app (tinyurl.com/2tzd8nrj) that lets you browse the web anonymously on your phone or tablet. Apple's restrictions prevent it from working on an iPhone or iPad, so Tor recommends you combine Onion Browser (onionbrowser.com), which was "developed by someone who works closely with the Tor Project", with its VPN Orbot (tinyurl.com/583hf847).



OnionShare lets you share and receive files privately over the Tor network.

Hide your online activities with a free VPN



A virtual-private network (VPN) is the most reliable way to access the web anonymously, because it encrypts your internet connection across your entire device, not just within your browser (like Tor Browser does). But VPN subscriptions can be expensive, and free services usually have catches—from tight data limits and poor choice of servers to dubious privacy policies that let them collect and share your data.

One of the best options is the free version of ProtonVPN (protonvpn.com/free-vpn), which offers unlimited monthly data, with no ads and a strict no-logs policy. It has a 'kill switch' that takes you offline when you lose your encrypted connection, so your anonymity is never compromised, and a 'stealth mode' that disguises the fact you're using a VPN. However, this mode is currently only available in the mobile and macOS apps, not the Windows program.

Previously, ProtonVPN's free plan let you choose from servers in the Netherlands, Japan, and the US, but it now randomly assigns one when you click its Quick Connect or 'Change server' buttons (see screenshot below).

This makes it less useful for unlocking geo-restricted content than for disguising your online activities, though it recently added free servers in Poland and Romania. Upgrading to ProtonVPN Plus for $9.99 a month gives you access to over 4,500 servers in more than 90 countries, and lets you use the service on up to 10 devices (the free version limits you to one).

Alternatively, Windscribe's free VPN (tinyurl.com/5n8msn68) offers 10GB of data a month (2GB until you confirm your email address) and access to servers in 10 countries, including the US, UK, Canada, France, and Germany. Its stealth mode is available in its desktop and mobile apps, and its 'split tunneling' feature lets you exclude programs from its protection.



ProtonVPN is one of the few free VPNs to offer unlimited monthly data.

Share and receive files anonymously



You can use Tor Browser—or a VPN—to download files from websites without revealing your identity or location, but it's less easy to share files without compromising your privacy. For that, you need OnionShare (onionshare.org), which lets you send and receive files securely and anonymously over the Tor network.

Install the OnionShare app on your PC (it's also available for macOS, Linux, Android, and iOS), click 'Connect to Tor', and select Start Sharing on the Share Files tile. Add the files or folders you want to share, and click 'Start sharing'. This will generate an onion address your intended recipient can enter in Tor Browser to access the shared items—click Copy Address to paste it into an encrypted email or chat message. You also need to send the other person the private key generated by OnionShare, so they can unlock the download. Click 'Stop sharing' to remove the files once downloaded.

To allow someone to send you files through Tor Browser, click Start Receiving on the Receive Files tab, then Start Receive Mode to generate another onion address and private key. They can enter these in the browser to upload files to you.

It may sound convoluted, but OnionShare is easy to use, and ensures that no third parties can intercept the files you're sharing—or detect where you and the other person are located.

PROTECT YOUR PRIVATE DATA

Fake your email address using an alias



There are lots of temporary email services you can use to sign up with websites, so you can avoid having to share your real name and email address. The trouble is that some don't let you return to your inbox later when you need to retrieve important account information. Free services also tend to be swamped with trackers, so aren't as private as you'd hope.

One solution is to create email aliases using SimpleLogin (simplelogin.io), which is powered by the Swiss privacy company Proton. Use an alias to register with a site or service, and SimpleLogin will forward all messages sent to the fake email address to your real one—without revealing the latter to spammers, scammers, and snoopers. You can even reply to emails using your alias, to maintain your disguise.

SimpleLogin's free plan lets you create up to 10 aliases, either using your preferred prefix and domain or by generating a random one (see screenshot below). Its browser extensions and mobile apps let you access your aliases on the fly, and disable them as required. SimpleLogin's Premium plan (to which you get a seven-day free trial) costs $30 a year, and includes unlimited aliases and mailboxes, as well as custom domains.

DuckDuckGo includes a similar feature, Email Protection (tinyurl.com/wyjzbvbs), in its mobile apps, desktop browser, and extensions. This lets you create an unlimited number of '@duck.com' addresses, which forward messages to your real email account and remove embedded trackers. It's currently in beta, but works very well.



Keep your real email address private by creating aliases with SimpleLogin.

Encrypt your private emails in Thunderbird



ProtonMail (proton.me/mail) and Tuta (tuta.com) provide free encrypted email services, but limit you to 1GB of storage. To keep your current email address, protect sensitive messages, and never run out of space, use the encryption features in Mozilla Thunderbird (thunderbird.net).

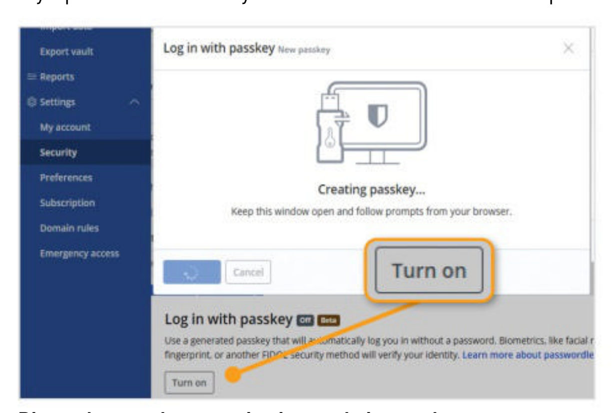


Thunderbird's built-in encryption tools keep your emails completely private.

Click the three-line menu button in the top-right corner of the main Thunderbird window, choose Account Settings, then End-to-End Encryption (1 in our screenshot). Click 'Add Key' 2, select 'Create a new OpenPGP key' and Continue. Choose your email address in the Identity menu, specify how many years your key should work for, and click 'Generate key'. Click 'Confirm', and Thunderbird will generate your OpenPGP key, consisting of public and 'secret' parts.

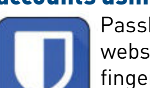
To send someone an encrypted message, you first need them to send you their public encryption key. Open the email that contains this key, double-click the '.asc' attachment, and click Import to save the key to Thunderbird. When you compose a new message to that person, click the Encrypt button, then write and send your email. Your public encryption key will automatically be attached, so the recipient—but no one else—can decrypt and read the message.

To share your public key with people you haven't privately messaged before, click the arrow next to Attach and select My Open PGP Public Key. This sends them an email attachment containing your key, so they can reply with their key and you can exchange encrypted messages.



Bitwarden now lets you sign into websites and your web vault using passkeys.

Protect your online accounts using passkeys



Passkeys let you log into websites and apps using your fingerprint, face, or screen-lock PIN, in the same way you unlock your PC or phone. Because this data is stored on your device rather than with the respective services, they're more secure and convenient than passwords.

Our favorite free password manager, Bitwarden (tinyurl.com/3unukxds), now supports passkeys to give you a simpler way to protect your data. Install the extension (tinyurl.com/yyj873vr), sign into your account, and visit a site that supports passkeys (see the list at passkeys.directory). Go into the Security section of your account settings, find the option to set up a passkey, and choose a login method—phone, tablet, Windows Hello, or security key. Bitwarden will offer to save the passkey—type Bitwarden when asked. The next time you visit, you'll be able to log in via the passkey.

Bitwarden recently introduced the option to sign into your vault with a passkey rather than a master password—click 'Turn on' under 'Log in with passkey' in its Security settings (see screenshot left). It has also added passkey support to the beta version of its iOS app (tinyurl.com/ymfca2hy).

WIPE ALL TRACE OF YOUR WEB ACTIVITIES

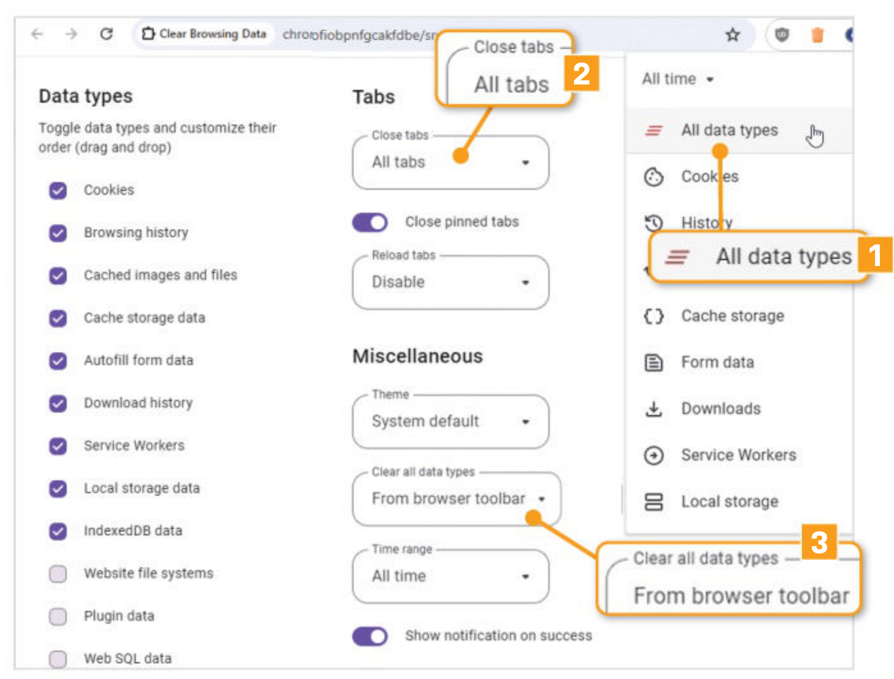
Delete all your browsing data in one click



One of the most useful features in DuckDuckGo's browser is the Fire button, which closes your open tabs and deletes your browsing data. This includes details of the sites you've visited; their cookies, caches, and favicons; and any permissions you granted them. It saves you the hassle of wiping these elements manually, keeps your activities private, and allows you to start your next browsing session with a clean slate.

You can add a Fire button-style function to other browsers by installing Clear Browsing Data for Chromium (tinyurl.com/2xh7fyr4 and Firefox (tinyurl.com/yeym8fm2). This lets you delete your cookies, cache, form data, history, and more by clicking its toolbar button and choosing the relevant option. Alternatively, wipe all browsing data in one go by selecting 'All data types'.

To specify which data to include, go into the extension's Options and tick the boxes in the left-hand menu. You can more closely replicate DuckDuckGo's Fire button by setting Clear Browsing Data to delete all data types and close all tabs **2** from its toolbar button **3**—switch off 'Ask before removing data' to skip the confirmation prompt.



Clear Browsing Data deletes all your browsing information with a single click.

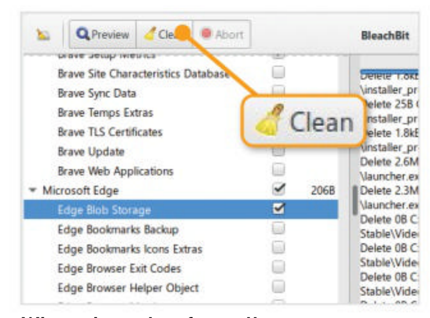
Clear data from all your browsers in one go



If you switch between multiple browsers, it's easy to forget how you may have compromised your privacy, such as by failing to sign out of a personal account or delete details of sensitive searches. Rather than open each browser in turn, wipe everything in one go using BleachBit (www.bleachbit.org).

This clean-up tool detects which browsers you have, and lists the types of data you can delete, including cookies, caches, searches, browsing history, and site preferences. For additional options, and to include browsers not identified by default, click the menu button, choose Preferences, and tick 'Download and update cleaners from community'. Click 'Save', and you'll see a list of browser settings, including 'blob storage' (unstructured data from online services).

Tick the boxes next to the items you want to wipe—or the box next to a browser's name—and click Preview. BleachBit will list the elements to be removed and tell you how much drive space you'll recover. Click 'Clean' to purge your browsers of private data and junk files.



Wipe private data from all your browsers in one go using BleachBit.

Remove private data from photos and videos



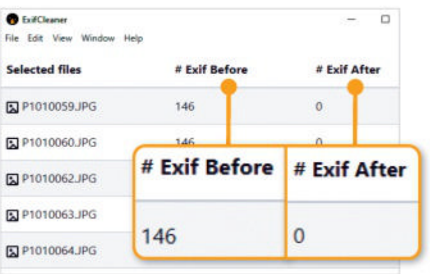
Digital cameras and smartphones record information about photos you take in the form of EXIF metadata. This is stored in the image file, and includes details of when and where the shot was taken and the device used.

Although this metadata is useful for organizing photos by date and location, it poses a privacy risk. Strangers who study the EXIF data can identify where you live and where you've been from the GPS coordinates. For this reason, it's wise to remove location data from these images.

The best free tool for this is ExifCleaner, which you can download from tinyurl.com/y4r7hfw6—click the 'ExifCleaner-3.6.0.exe' link under Assets. Drag and drop images into the program window, or click Open in the File menu to select them manually, and ExifCleaner will automatically remove EXIF data from the file, and show 'before' and 'after' figures.

The program supports all main image formats, including JPEG, PNG, BMP, GIF, and TIFF, and can strip metadata from videos. Although it hasn't been updated since 2021, it has a clean bill of health on VirusTotal (tinyurl.com/yc3xf42d).

You can remove metadata from photos on your mobile device using free apps such as Photo Metadata Remover for Android (tinyurl.com/3epwh68f) and Exif Metadata for iOS (tinyurl.com/38mxjyp7).



Use ExifCleaner to remove metadata from photos before sharing them.

TEST YOUR PRIVACY USING ONLINE TOOLS

Test the privacy of your web browser



Don't assume that your browser's own privacy settings will prevent websites from identifying and tracking you. Instead, Electronic Frontier Foundation's Cover Your Tracks (coveryourtracks.eff.org), tick the box 'Test with a real tracking company', and click Test Your Browser.

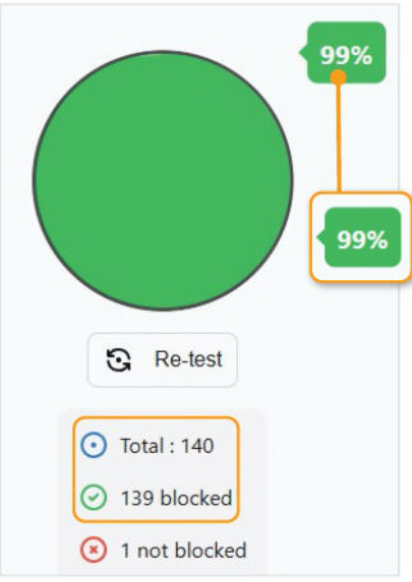
The site will tell you if your browser is blocking tracking ads, invisible trackers and fingerprinting, and how much identifying info you're leaking—scroll to the Detailed Results section to learn what they are. In our tests, only Tor Browser and Brave (with 'aggressive' fingerprinting enabled) offered complete protection.

Confirm your ad blocker and VPN are working



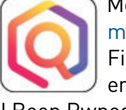
Although we recommend uBlock Origin, there are lots of good alternatives—just make sure your choice works as promised. Adblock Test (tinyurl.com/wy3nuhac) tests the effectiveness of your blocker against ads, tracking scripts, analytics tools, social-media trackers, and other intrusive elements, and gives it a protection percentage score. Try carrying out its test with your ad blocker enabled and disabled to compare the difference. In our test, uBlock Origin achieved 99 percent protection, blocking 139 out of 140 elements, but without it, Chrome scored only three percent, blocking just four.

Similarly, you can check that your VPN or other anonymity tool is disguising your IP address by visiting IPleak.net (https://ipleak.net). If your real location and ISP are shown in the 'IP address details' box, your privacy isn't being properly protected.



Test your ad blocker to make sure it's effectively blocking trackers.

Check if your data has been breached



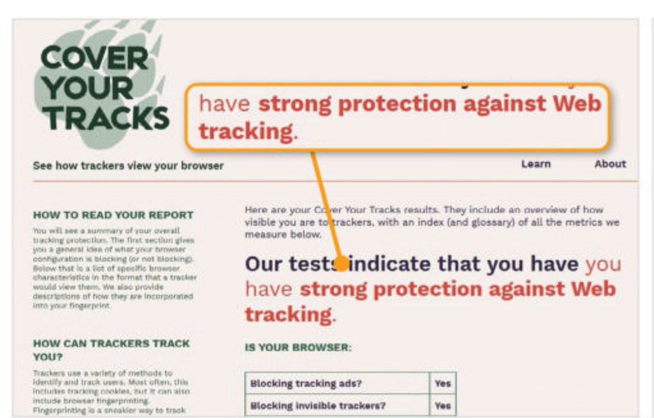
Mozilla Monitor (monitor.mozilla.org), formerly called Firefox Monitor, checks your email address against the Have I Been Pwned database to determine if it's been involved in any data breaches. If so, it displays 'Action needed' warnings, tells you what info is affected, and lets you click 'Fix all exposures' to get advice on securing your accounts. Mozilla Monitor works in all browsers, and is integrated with Firefox's password manager to alert you when your details have been compromised. You need a Mozilla account to use the free tool. It also has a paid-for Plus plan, which removes your personal info from data-broker sites.

CAN YOU CHAT PRIVATELY WITH AI TOOLS?

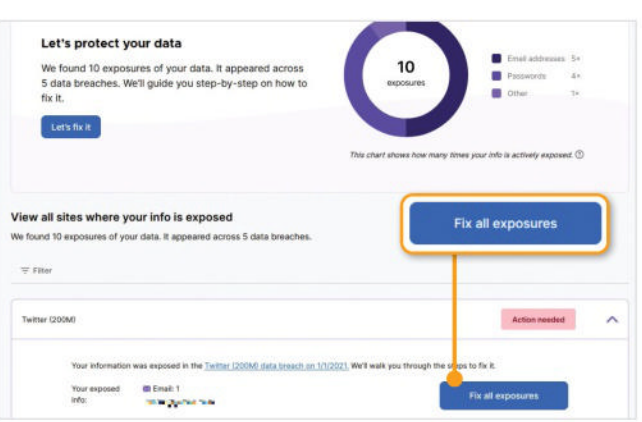
The rise of AI chatbots, such as ChatGPT and Microsoft Copilot, has led to privacy concerns over the way they collect your data. Queries and commands you enter are stored and shared to train AI models, but they're also linked to your online identity, including your location, email, and phone number.

Last year, ChatGPT's owner, OpenAI, addressed privacy worries by adding the option to let users switch off 'Chat History & Training'. You'll find this in the Data Controls section of the tool's Settings on the ChatGPT website and its mobile app, where you can also clear your chat history. But this merely stops your chats being used for training purposes—OpenAI will still store them for 30 days, and link them to you.

Brave's new Leo chatbot (brave.com/leo) is more trustworthy, because it doesn't require an account, collect information such as your IP address or, store your chats. You could also try the Android app 'Chat with AI – Incognito' (tinyurl.com/2tkwc5v9), which claims to provide 'complete anonymity' by not requiring an account, storing your data or allowing third parties to track you.



Cover Your Tracks tests your browser's protection against tracking and fingerprinting.



Mozilla Monitor alerts you when your passwords are involved in data breaches.

CENTERFOLD

PERFORMANCE GEAR LAID BARE

1 POWER UP

The upright rectangular design of the Orbi range is a familiar sight in many homes and offices, but the Orbi 970 has had a bit of a facelift. The sheer speed of Wi-Fi 7 requires more power than previous models, so the new Orbi units have a taller, more cylindrical design that stands at 11.5 inches high, and houses no fewer than 12 internal antennae.

2 APP OOPS

The Orbi's hardware features are state of the art, but the app is a mixed bag. The initial setup process is fine. However, the app requires you to provide your email address in order to create an account before you can finish setup, and then hits you with an ad for technical support before you can even look at your new network settings.

Netgear Orbi 970

NETGEAR WAS QUICK off the mark with its RS700S, one of the first routers we've seen supporting the latest Wi-Fi 7 standard. The Netgear Orbi 970 mesh system was announced around the same time, and promised to be one of the best mesh Wi-Fi systems on the market. It's taken a while to hit retail, but it's finally ready to ramp up your home networking performance.

The Orbi 970 goes further and faster than the standalone RS700 with a three-piece 'whole home' mesh system. Capable of a top speed of 27Gbps and covering areas of up to 10,000 square feet, there is one catch: It's phenomenally expensive, with the three-piece system coming in at $2,299. Ouch.

The cost of the Orbi 970 will probably rule it out for most home users, especially those with domestic broadband services running at around 150Mbps. However, Wi-Fi 7 isn't just about speed; it also brings improved capacity and reliability, and the Orbi 970 claims to provide fast, reliable connections for up to 200 devices on your home or office network. It also includes new Wi-Fi 7 features, such as 'preamble puncturing', which helps to reduce outside interference and improve the reliability of your Wi-Fi connections.

While there aren't that many computers or mobile devices that currently support Wi-Fi 7, the Orbi 970 will still be backward-compatible with older devices that are still using Wi-Fi 5 or 6, so it's a good way of future-proofing the Wi-Fi network in larger homes.

–MAXIMUM PC

3 BUILD YOUR NETWORK

This three-piece system can cover areas of up to 10,000 square feet. However, there's also a two-piece option available, which covers up to 6,600 square feet for a still rather hefty $1,699. If you're a Silicon Valley zillionaire, you can extend coverage even further with add-on units for a mere $900 each.



HOW TO BACK UP EVERYTHING



Want to back up your important data for free? *Nick Peers* has your safety net

WE ALL KNOW how priceless our personal data is. You can't recreate photos and hand-crafted documents from thin air. Another crucial commodity is time: how damaging would it be to spend more than a few hours (never mind 2-3 days) recovering your system to a usable state?

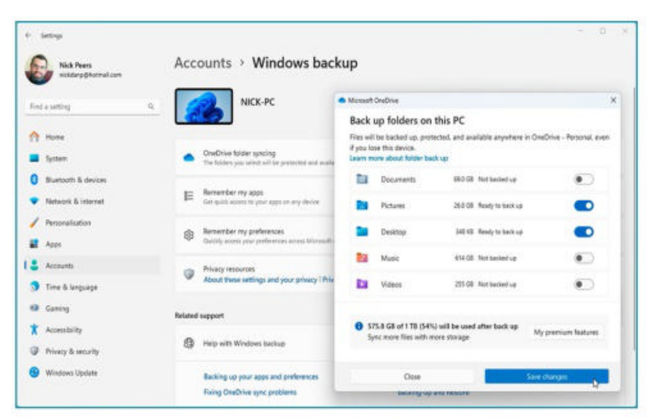
Armed with the right backup regimen, you'll never have to worry about losing more than a few minutes' work again. Over the next seven pages, we'll reveal how to protect not just your main Windows PC and everything on it, but your Linux machines, too. For good measure, we'll help you back up key photos, settings, and apps on your iOS and Android devices, too.

Better still, for the most part, we'll show you how to do all this at no cost to yourself. We'll even reveal a trick for swapping backup space with a trusted friend or family member so you can avoid monthly fees for securing a copy of your data offsite. Should the worst happen, we'll show you how to get your PC and its contents up and running, too. Read on to banish data loss to the annals of history.

LET'S START with the most important device of all: your main Windows PC. What we're looking for is a multi-layered solution. First, there's the need to protect all your personal files and folders. You might also want to back up selected apps and settings, such as email. Finally, you want a fail-safe backup of your entire system, so you can quickly get up and running again in the event of disaster.

In the past, all the tools you needed could be found in Windows: File History for files, and Windows Backup and Restore for the fail-safe backup. Now, Microsoft has decided to focus exclusively on its cloud sync to the point where the 'new' Windows Backup tool in Settings is little more than a front-end for syncing key personal folders, Microsoft Store apps, and selected Windows settings to your OneDrive storage.

The problem is twofold. First, it's not particularly comprehensive, which might explain why File History still lives on behind the scenes. Second, it assumes that you want to store your data on Microsoft's servers. Even if you have a Microsoft 365 subscription to use, can you trust Microsoft with keeping your personal data safe?



Windows 11's latest backup tool is intrinsically linked to OneDrive.

BACK UP PERSONAL FILES AND FOLDERS

When it comes to protecting your personal data, you have two choices: a traditional regular backup of specific files or folders to a local hard drive using a schedule, or a sync-based option that typically backs up data to the cloud or on a network device in real time. The latter ensures your critical backups are always virtually up to date, while also retaining earlier versions for additional redundancy. Examples of sync-based storage include OneDrive, Google Drive, and the self-hosted Nextcloud.

We recommend mixing both methods for additional protection—OneDrive users should consider using the main client rather than rely exclusively on Windows Backup. Like all cloud-based clients, you'll need to ensure all data you wish to be backed up resides in the client's parent directory, such as C:\Users\Username\OneDrive or D:\Nextcloud).

When it comes to backing up files locally, you have a choice of two approaches: Duplicati (https://duplicati.com), or Hasleo Backup Suite (www.easyuefi.com), both of which are free. Duplicati installs as a web-based service, so is configured through your browser—see the May 2023 issue for a complete tutorial on using it. One compelling reason to choose Duplicati is that you can store backups both locally and online through many cloud storage services, including OneDrive, Google Drive, Dropbox, and Mega.nz. Better still, these backups can be encrypted separately, so you don't need to trust your cloud provider's own security.

However, if you don't want to use your cloud storage in this way—or you have no cloud storage subscription at all, and would like to store your files remotely in a different way, as outlined in the free remote storage box—then Hasleo Backup Suite could be a better choice, particularly as you'll be using it to take fail-safe image backups.

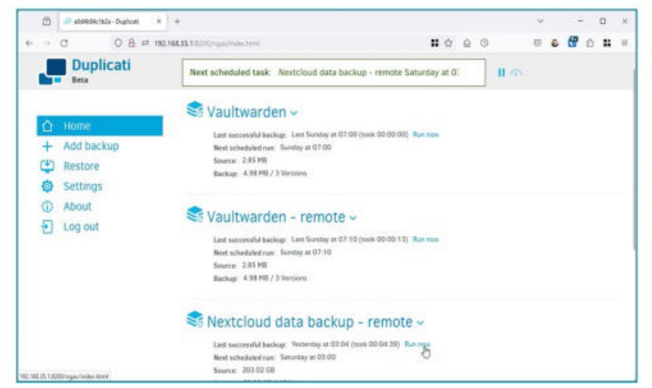
BACK UP FILES WITH HASLEO

Launch Hasleo and choose Backup > File Backup. The folder pane provides a means of browsing your computer for folders and/or files to back up. You may wish to create a single all-encompassing backup job or individual jobs for certain folders. Whichever option you choose, select what to back up before giving your task a suitably descriptive name.

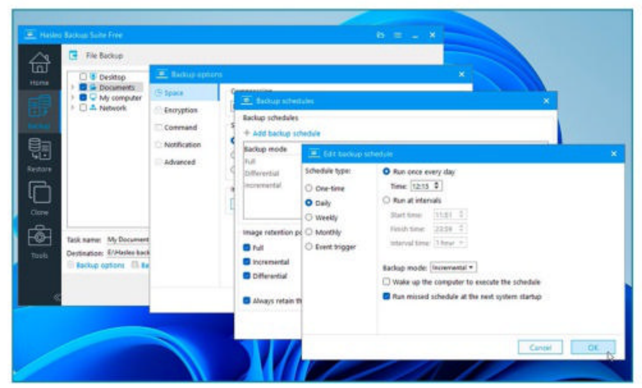
Click the folder icon next to choose where to store these backups—it goes without saying that this should be a separate physical drive to your original data. Next, click 'Backup options'. Click Edit under 'Image retention policy', followed by 'Add backup schedule'.

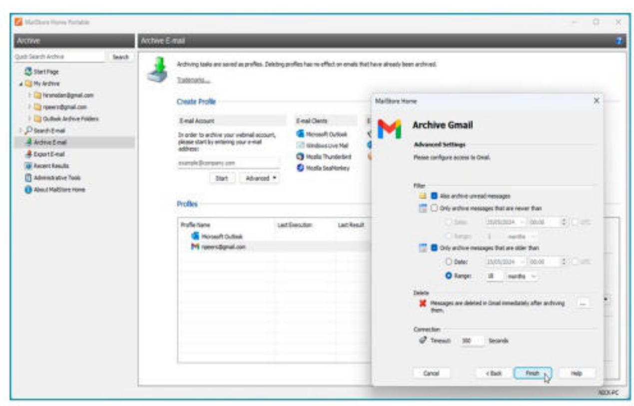
Hasleo supports both differential and incremental backups to save space, so we recommend running three separate tasks: one monthly full backup, a weekly differential backup, and as many incremental backups as you need. Start by creating the monthly backup—be sure to change Backup mode to Full, and check 'Run missed schedule at the next system startup', before clicking OK. Next, create a weekly differential backup, followed by a daily incremental backup. With this last backup, you can create a single daily backup or choose 'Run at intervals' to take multiple backups between two specific points (say, working hours). The more frequently you back up, the less data you risk losing.

Once your backup schedules are in place, examine the image-retention policy to determine how many of each type to keep. Check each box (Full, Incremental, Differential), and choose



Duplicati can handle local and offsite backups.


Make sure your data is backed up at least once a day.



Create a searchable (and easy to back up) archive of your email.

whether to keep a select number of backups, or for a specific period (days, weeks, months or years). Check 'Always retain the first backup' to keep the oldest backup you create. How long you keep backups is up to you—if you're only interested in having access to recent versions of files, then 1-3 months for each type will prevent your backup drive from filling up. Click OK.

Work your way through the other options—your backups will be stored in compressed files to save more space, which you can encrypt with a password using AES256 encryption. You can also receive email notifications if backups succeed (or fail). Most settings are optional, but do select 'Check the integrity of the backup image files on completion'—after all, a corrupt backup isn't any better than having no backup at all.

Once done, click OK, click 'Backup schedules' to verify that it's noted your schedule, then click OK, followed by Save. Finally, click Backup to take your first backup.

BACK UP APPS AND SETTINGS

What about other key data, including personal settings? Don't be fooled by the promise that your preferences are backed up in Settings under Accounts > Windows backup. These cover just a small selection of Windows settings.

Let's start with your email. Whether your mail is stored in the cloud or on your PC, MailStore Home (www.mailstore.com/en/products/mailstore-home) allows you to archive old emails from a range of sources, including Outlook and Thunderbird, as well as Gmail, Yahoo! Mail, or indeed, any POP3 or IMAP account. After connecting your account, you can also choose to free up space by deleting any emails after they've been downloaded to your new archive. However, if you do this, make sure your MailStore Home archive file is backed up separately—given the potential size of the file, we recommend using Duplicati or Hasleo rather than entrusting it to your cloud provider.

Most browser settings can now be backed up by signing into an account in the browser—Edge is linked to your Microsoft account, and Chrome to Google, while the likes of Firefox, Opera, and Vivaldi offer their own proprietary accounts. If you don't trust the cloud or want the added security of an offline backup, consult your browser's documentation or forums for details of locating your profile folder—for example, Firefox users should visit https://support.mozilla.org/en-US/kb/back-and-restore-information-firefox-profiles for full step-by-step instructions.

When it comes to other programs, you may be able to quickly and easily store their settings for free with the help of CloneApp (https://github.com/builtbybel/CloneApp), which supports around 250 apps and tools. Failing that, look for an export settings option or consult its documentation and support forums.

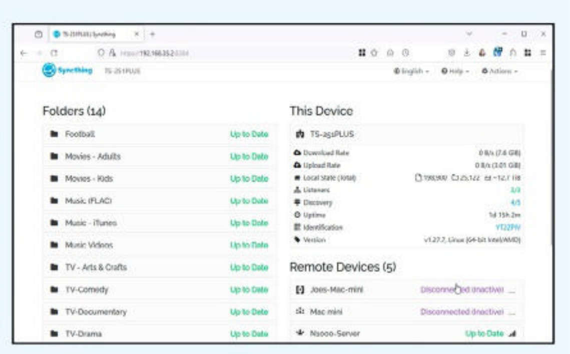
FREE REMOTE BACKUP STORAGE

If you don't trust the cloud or can't afford to pay for a cloud storage plan, then one way to get secure offsite storage is through a mutual arrangement with a friend or family member. That way, you get to store your data in a remote location without having to pay an ongoing fee for the privilege.

From here, you have two choices: you can agree to trade storage space, with each person giving up some of their own storage to the other. Alternatively, you can look into swapping hard drives—choose a network-attached model for 24-7 access and ease of setting up. This could be your own self-built server, or a NAS from the likes of Synology or QNAP, basically one capable of running Syncthing (https://syncthing.net).

The beauty of Syncthing is that you can set things up at home, complete the initial sync of your data over your own network, and then pass on the drive to your friend. Once powered up at their end, Syncthing will continue to keep your data in sync going forward. For a complete guide to setting up and using Syncthing, check out the July 2023 issue.

What's the best way to set up Syncthing for this purpose? Ideally, you back up to a local drive first, then simply use Syncthing to transfer the compressed backup to your remote storage. One additional security feature is that Syncthing allows you to designate this remote storage as 'untrusted' in the Sharing tab when setting up the connection. Choose a strong but memorable password or passphrase, and your data will be encrypted making it unreadable at the other end. For more details on trusted connections, including the steps you'll need to follow should you ever have to decrypt this data to recover it, see the Syncthing manual (https://docs.syncthing.net/v1.27.7/users/untrusted.html).



Syncthing makes it easy to share backups between friends and family.

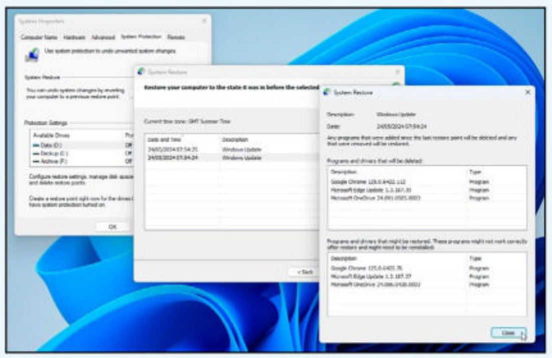
SYSTEM SNAPSHOTS

It doesn't matter how diligent you are—over time, your Windows installation starts to get bogged down with leftover files, Registry entries, and other unwanted elements from long-forgotten program installations. And then there's the aftermath of a Windows Update or driver install gone wrong, leaving your system in a semi-working state. How can you avoid the rigmarole of a complete Windows reinstall?

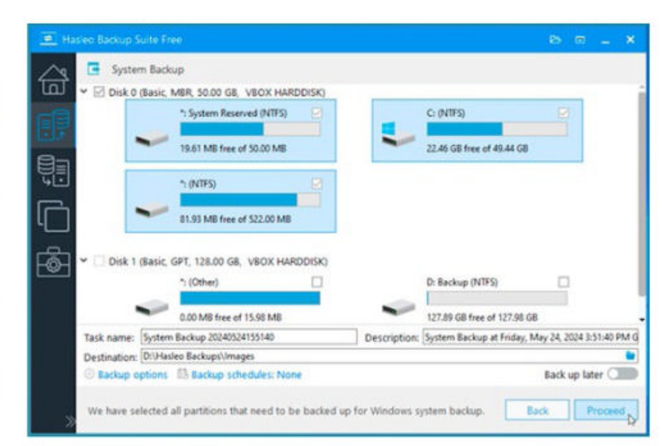
One option is to restore your last drive image, but if that's more than a few days old, you could end up losing more than you bargained for. Windows has one solution in the form of System Restore, but it's rarely switched on by default. To use it going forward, type 'System Restore' into the Search menu and choose 'Create a Restore Point'. Select your system drive and click Configure to verify it's switched on, and that it's been allocated enough space (typically 5-10 percent, depending on the size of your drive). Going forward, it should take regular system snapshots, as well as snapshots before key events like application installations and updates.

Should you need to roll things back, click the 'System Restore…' button from the same dialog. You'll be shown a recommended (the most recent) Restore point—click 'Scan for affected programs' to see what changes will be reversed, followed by Close and Next to undo those changes. If necessary, select 'Choose a different restore point' to go further back in time.

System Restore isn't comprehensive, so there may be times where it can't fix things to your liking—in those situations, you may be forced to rely on an older image-based backup. Alternatively, take a look at RollBackRx (around $100 after free trial, https://horizondatasys.com/rollback-rx-time-machine) that provides you with the ability to roll back your entire PC in seconds, even when Windows refuses to boot.



System Restore remains a viable way to undo certain system changes.



Create a full fail-safe backup of your entire hard drive.

BACK UP YOUR ENTIRE SYSTEM

Our final backup is the fail-safe one. It will create an exact cloned copy of your Windows system drive and everything on it. This will allow you to restore Windows to a working state with minimum disruption—even if your entire installation is lost. You can even use it to restore Windows to a new hard drive if your original drive fails.

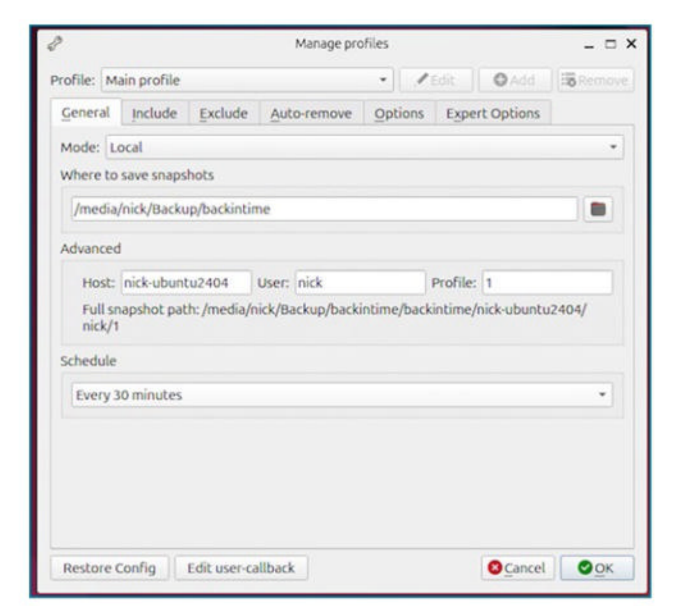
Once again, we're using Hasleo, and the process is broadly similar to the folder-based backup you created earlier. This time, choose System Backup under Backup to pre-select all the partitions required to run Windows. As before, give it a suitably descriptive task name and choose a location on your backup drive. Work through the backup options as before. Again, we recommend setting up the same three schedules—monthly full, weekly differential, and daily incremental backups. This means that you'll never have to roll back more than a single day.

Once the initial backup has completed (and been verified), switch to the Tools section. Here, you'll see an Emergency Disk option—click this to set up your emergency boot media. In most cases, you won't need to add any additional drivers, so simply check 'Download WinPE components' if they're not already on your PC, and click Next. Hasleo will build the emergency boot media and then give you the option of writing it to an empty USB flash drive (8GB or larger), or exporting it as an ISO file for either burning to DVD or adding to your Ventoy (https://ventoy.net) bootable flash drive.

Ideally, you won't rely on a single backup location for your drive images—if you have a second drive, then repeat the above steps to set up a second backup job pointing to the second drive. Make sure it runs on a different day or time of day to avoid conflicting with the other backups that you're performing. If you have network-attached storage, an easier option might be to set up a Syncthing job to keep the contents of your backup folder synced to your network rather than trying to save directly to the network drive each time.

BACK UP YOUR LINUX PC

If you have Linux installed somewhere—either as a complete installation with desktop environment, or as a minimal server install—you'll be wanting to protect that, too. When it comes to your personal data, you should find that everything you need to back up is in your personal home folder (/home/username). In addition, a system snapshots tool provides you with System Restore-like functionality. When it comes to taking a full drive image of your system, however, things get a little more involved.



Back in Time covers your file and folder backup needs in Linux.

Let's start with file-based backups. If you're running a server, then we recommend Duplicati, because it provides you with a web-based interface to simplify backup management. Desktop users should use Back In Time, which isn't included by default in either Mint or Ubuntu. Install this through the Synaptic Package Manager or Terminal (sudo apt install backintime-qt).

Once installed, launch the app and select your backup drive as the location for your snapshots, plus set a schedule—typically five minutes to an hour. Once done, switch to the Include tab to select the folders and/or files you want to back up. Use the Auto-remove tab to manage backups to prevent your drive filling up.

You can create multiple profiles, too, allowing you to parcel out your backups so that those folders that change more frequently, like your Documents folder, are backed up more often.

LINUX SYSTEM SNAPSHOTS

When it comes to system snapshots, TimeShift is our tool of choice. It comes preinstalled in Mint (look under Applications > System), while Ubuntu users can install it through the App Store (search for timeshift under 'Debian packages'). Follow the wizard, selecting RYSNC if prompted. Wait for TimeShift to estimate how much space is required to back up your system, then choose where to save your snapshots and how often they should be run. RSYNC ensures that after your first backup, snapshots only record the changes to your hard drive to minimize the storage used. Once done, click Create to set up your first snapshot.

TimeShift can also be used from the command line (sudo apt install timeshift). Use the --help flag (timeshift --help) to see how to use it, but start by determining which drive to store your snapshots on:

```
sudo timeshift --list-devices
```

The following example sets up TimeShift to take daily snapshots of your system and store them on the sdb1 drive:

```
sudo timeshift --create --comments "Daily backup" --tags D
--snapshot-device /dev/sdb1
```

LINUX DRIVE IMAGES

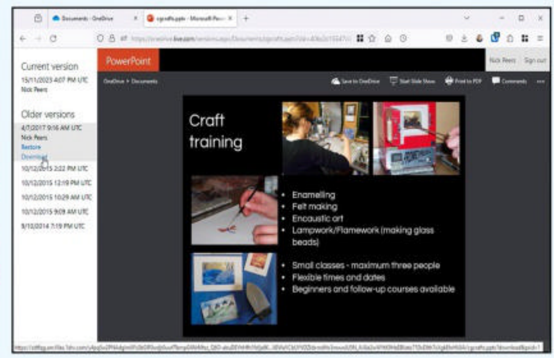
If you want to take a complete drive image, you can only do so safely from outside Linux. This means creating bootable media—

RECOVER OLDER FILE VERSIONS

Both our recommended backup regimens for files and folders come with an added benefit: you're not just storing the latest version of your files, you're saving different versions, too. Sometimes, data loss isn't the complete loss of a file, but the fact that you've made changes that you regret doing in hindsight.

If you're backing up files and folders through Hasleo, rolling back involves clicking Actions next to your data backup job on the main screen and choosing Restore. Hasleo will show you the date and time the backup was taken. To restore an earlier revision, click 'Change version' to reveal a popup menu showing all previous backups by date and time. Pick the one you want to restore from, then use the folder picker to browse to the file you wish to restore. Once selected, we recommend using 'Restore to...' to select a different folder, so you can compare this version with your current one. If it's not what you're looking for, try a different version. This principle is the same when restoring individual files through other backup tools offering multiple versions, including Duplicati and Back in Time in Linux.

If you're backing up your files to the cloud—including your own self-hosted Nextcloud instance—then you'll have more flexibility over which version to restore, as more frequent backups result in more file versions to choose from, particularly with more recent changes. Restoring these files usually requires you to log in to your account through your web browser—in the case of OneDrive, for example, locate your target file and click ... next to it before choosing Version History. Depending on the file type, you'll be able to compare versions on screen, then choose to either download a copy or restore it as the current version.



Restore earlier versions of OneDrive-hosted documents through your browser.

RESTORE YOUR SYSTEM

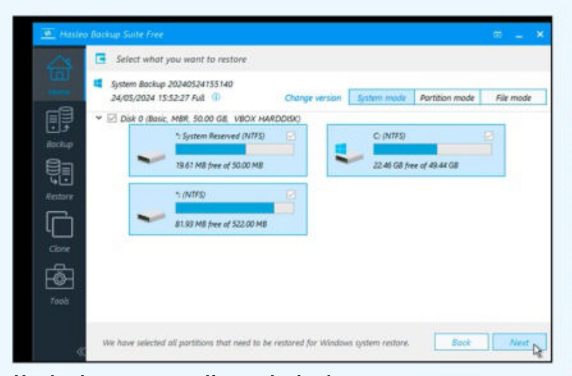
The unthinkable has happened: disaster has struck, and you need to restore your PC to its previous working state. This is where your backups prove their worth. If you're restoring your Windows system and are unable to boot into any flavor of Windows (including Safe mode), simply boot from your Hasleo rescue media, pressing any key when prompted to boot from CD or DVD.

You'll see the familiar Hasleo interface appear, and it should scour your drives looking for backups. Locate your most recent system backup by its time and date and click the Actions button, selecting Restore. By default, all the partitions required to run Windows should be selected—click Next to verify that 'Restore to original location' is selected, as well as your Windows drive. Click Next, followed by Proceed, in order to restore your PC to a working state.

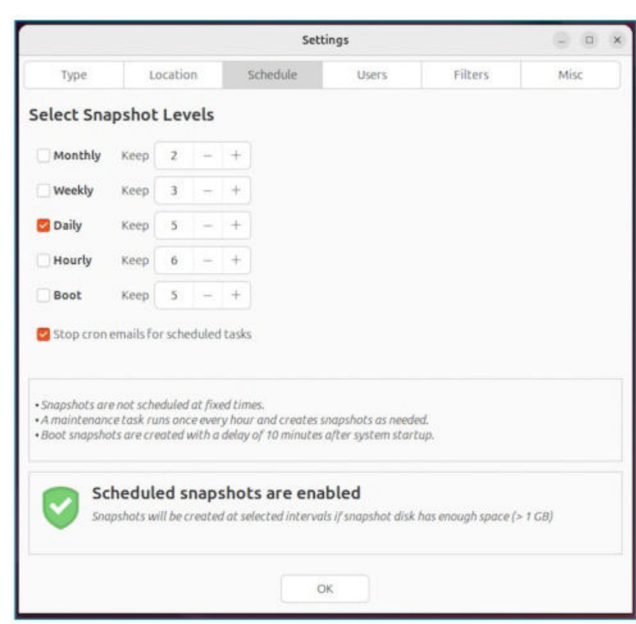
If you run into problems with your Linux installation, then your first port of call is TimeShift to see if you can simply roll back to the last working state (or indeed, an earlier state, if required) from within Linux itself. Launch the app, select your last working snapshot, and then click Restore—make sure your boot device is selected under / while /boot, and /home can be left as 'Keep on Root Device' in most cases. You can run TimeShift from the command line or install it from live Linux media if necessary:

sudo timeshift --restore

If you plan to restore an entire disk image, then you'll need to use your Linux live media as before to access Disks. This time, however, you click the vertical ellipsis button and choose 'Restore Disk Image...' Click the folder button to locate your latest backup image, and click Open, followed by 'Start Restoring...'



Hasleo's rescue media works in the same way as the main program.



Use TimeShift to add System Restore-like capabilities to Linux.

one option would be to boot from your Ubuntu installation media and choose to 'try' Linux. Once you're at the familiar desktop, open the Disks utility, select your boot drive, and click the vertical ellipsis button above it. From the popup menu that appears, choose 'Create Disk Image...' and then select your backup drive as the destination.

You'll also find that Linux is well stocked for other forms of backup and sync—Ubuntu users should visit Settings > Online Accounts, where you'll find options for connecting to Google, Microsoft 365 (OneDrive), and Nextcloud. Other cloud providers, including Dropbox (www.dropbox.com/install-linux), may offer official clients. If yours doesn't, see if an unofficial client has been developed elsewhere, or consider switching to another provider who does support Linux.

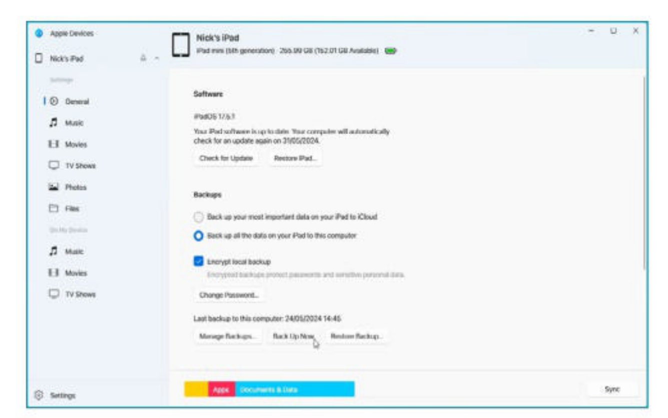
BACK UP YOUR MOBILE

Both Android and iOS come with built-in backup tools from Google and Apple respectively, while some Android manufacturers—including Samsung—may offer their own proprietary backup services. These should be treated with care, as while they'll get you up and running again, they may not be a good choice if you plan to change phone (and manufacturer) in the near future.

While it's tempting to assume that all is being taken care of behind the scenes, it pays to verify what's going on, plus where gaps may need filling with specific apps or data. Apple users should navigate to Settings, then tap your account name, followed by iCloud. You'll need to tap iCloud Backup to back up your iPhone or iPad to the cloud, but you'll almost certainly need to be on a paid storage plan for this to be effective. It's also not a full backup.

A cheaper—and more comprehensive—option is to use your PC. Apple recently retired iTunes in favor of separate apps: Apple Music, Apple TV, and Apple Devices. You'll need to first uninstall iTunes, then install Apple Music (and Apple TV if you've purchased movies or shows from it). Once done, install the Apple Devices app to back up your iPhone or iPad.

Start by connecting your iOS device to your PC with a USB or USB-C cable, then open Apple Devices. Select your device in the sidebar, followed by General. Select 'Back up all the data on your iPhone/iPad to this computer', check 'Encrypt local backup', and



Back up your iPhone or iPad to your PC.

enter a suitably strong—but memorable—password. Finally, click Apply, followed by 'Back Up Now'.

A full backup can use hundreds of gigabytes of space, and Apple Devices doesn't let you choose where to store those backups. Instead, it places them in separate folders (one per backup) inside C:\Users\Username\Apple\MobileSync\Backup. If—like us—your C drive is relatively small, you'll want to store them elsewhere, but there's no option to do so. The workaround is to create a junction link to C:\Users\Username\Apple\MobileSync\Backup. Rather than fiddle around with the command line, use a user-friendly tool like Symbolic11 (https://github.com/Benisgo/Symbolic11) to link that folder to another drive.

Once your first backup is complete, you'll need to remember to periodically connect your iOS device to your PC for a fresh backup. Apple Devices is also where you go to restore backups, while clicking 'Manage backups' allows you to remove older, redundant backups to free up space.

BACK UP ANDROID

Android users should open Settings > System > Backups to verify your current settings and schedule. You should see confirmation that your backup is stored online in your Google One account, along with a breakdown of how much space it takes—the vast bulk of this will likely be your photos and videos.

All Google users get 15GB of storage space for free, shared across your Google services. If you're running out of space, tap 'Photos and videos' to see how much your photos take up. If they're responsible for the bulk of your storage, you have a couple of options. The first is to tap Plan Settings to investigate upgrading your plan: a Basic 100GB plan costs $1.99/month ($19.99/year), while Premium offers 2TB for $9.99/month or $99.99/year.

If you can't justify the extra expense, then see if changing Backup quality to 'Storage saver' is enough to free up enough storage. If not, you can disable photo and video backup from your device using the switch at the top of the page, then investigate other options.

BACK UP MEDIA ELSEWHERE

If you're happy with backing up to the cloud, but don't want to put more money in the hands of either Apple or Google, then the good news is that you can upload your device's photos and videos elsewhere. If you're a Microsoft 365 user, for example, open the OneDrive app and tap Photos to see a notification that 'Camera backup is off'. Tap 'Turn on' to back up your photos to OneDrive instead.

If you've set up your own self-hosted Nextcloud instance (see the October 2023 issue), then you can back up to here, too. Another self-hosted option supporting both Android and iOS is immich (https://immich.app), which we featured in the Holiday 2023 issue.

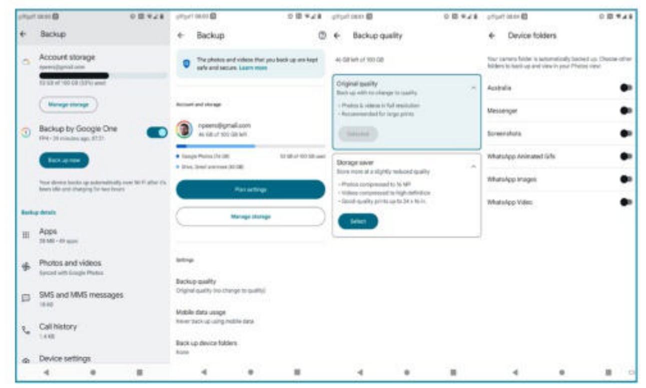
Also, remember that initial backups can take some time—check the app for any additional requirements. You may need to leave your phone plugged in and the app active for several hours in order to complete the initial upload, for example.

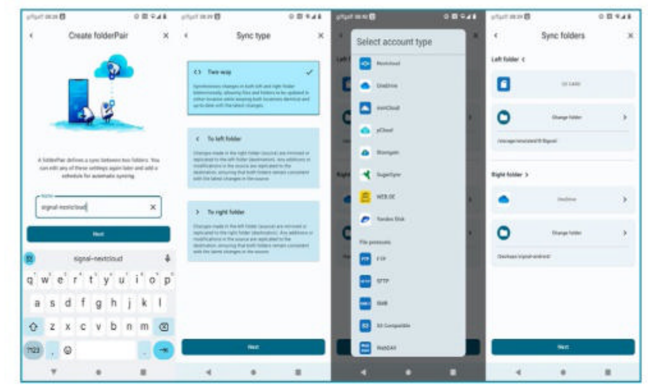
FILL IN THE GAPS

Not all apps are backed up by default to Google One or iCloud. If you're not using your phone's standard calendar, contacts and email app, check to see if it's backed up elsewhere (or is otherwise hosted in the cloud, in which case it's not an issue). You might also want to investigate what happens with your messaging apps—some, like Messenger, will store your messages in the cloud, while others require extra steps.

WhatsApp users should navigate to Settings > Chats > Chat backup to verify backups are on and to choose backup frequency (weekly by default) and whether to include videos (no by default). Signal users on Android (but not iOS) can also back up their chats from within the app, but only to a local folder: tap your profile icon and select Chats > Chat backups. Flick the switch to on—you'll be prompted to select or create a backup folder, then record the passphrase before enabling backups.

Another option, which can be used to back up any folder on your Android device, is FolderSync. The app is free (ad-supported) through Google Play, or you can purchase a Personal license covering five devices from its website (https://foldersync.io) for around $11. This supports a wide range of popular cloud services, as well as network protocols, allowing you to set up a fail-safe backup for just about any file on your phone.

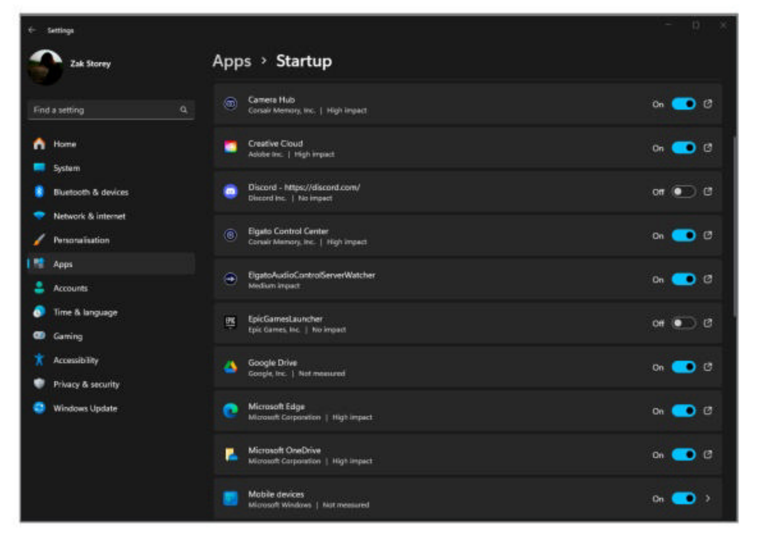

Take the time to check—and tweak—your phone backups.


Back up any folder on your Android phone to the cloud with FolderSync.

HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

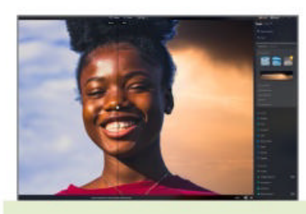
TIP OF THE MONTH



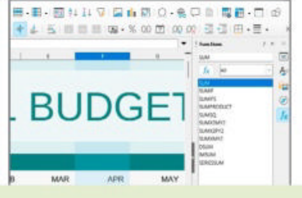
STARTUP PURGE

Want to speed up your login time? Fed up with every app under the sun launching within 2.5 seconds of you signing in? Us too. Fortunately, there's a super-quick and simple way of stopping apps from opening up in Windows. Head to the Start menu, and type 'Startup Apps'. Hit Enter, and you'll get a list of all the programs installed on your machine, with the option to disable them from loading on Windows launch/login.

MAKE – USE – CREATE



62
Edit your photos in Luminar Neo



66
Master LibreOffice 24



70
Use your tablet as a PC monitor



ZAK STOREY
CONTRIBUTOR

TEST BED TWEAKING

It's been a busy year for me, or at least the last six to eight months. I left a job that wasn't really working out and pivoted to being a freelance writer. It was terrifying at first—the lack of security, the piecework lifestyle, and pay. But as I reflect, it's given me a host of opportunities and knowledge that I wouldn't have otherwise had.

One of those is now being a top CPU, GPU, and SSD reviewer for multiple different outlets. That means from Jan 2024, I've been testing Intel's 14th gen, moving on to AMD's latest X3D chips, every GPU you could think of, and too many SSDs to count. I needed a testbed to get the most out of those components without creating bottlenecks. Enter the Gigabyte RTX 4080, Dominator Titanium Memory, Asus Z790 ROG Maximus, and a host of iCUE stuff.

It worked a treat, but as Computex approaches, I'm starting to rethink things. There are two approaches: an approximation of an 'average' high-end system, complete with RGB lighting, and over-the-top 'gamer' branding and kit. Or, I could dump the RGB, pick up the best Noctua kit I can find, a decent AIO, and an open-air test bed.

I'll likely stick with that Crucial Pro Overclocking memory. Having XMP and AMD EXPO timings on a single kit is a lifesaver.

↘ submit your How To project idea to: editor@maximumpc.com



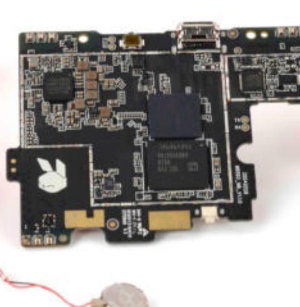
AUTOPSY

THIS MONTH WE DISSECT...

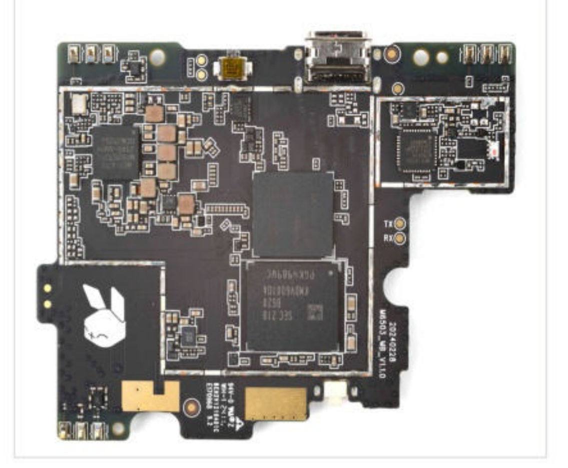
Rabbit R1 vs Humane



There's a lot of empty space inside the Rabbit R1, which is surprising, considering how bad the battery life is.

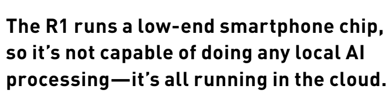








The Rabbit's non-clicky scroll wheel turns out to be a Hall Effect sensor, and has a magnet inside a roller wheel.

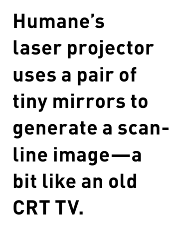


The R1 runs a low-end smartphone chip, so it's not capable of doing any local AI processing—it's all running in the cloud.

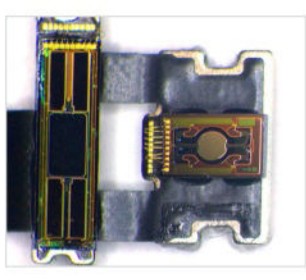


About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com



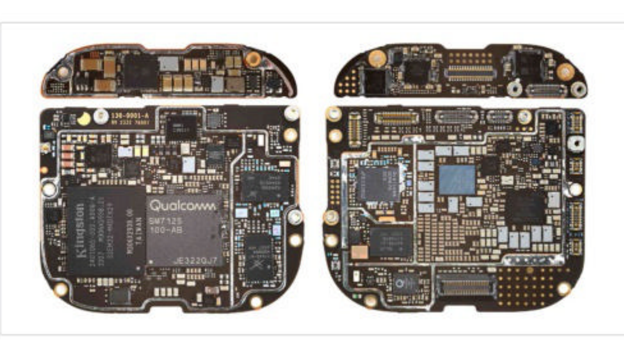
Humane's laser projector uses a pair of tiny mirrors to generate a scan-line image—a bit like an old CRT TV.







AI Pin



The mainboard powers all the local hardware, with the LLM being based in the cloud and only accessible with a Wi-Fi or cellular data connection.

The Humane AI Pin is physically the higher-quality device. Apparently, it was engineered by ex-Apple engineers, and it shows.



BACKGROUND

Are AI-powered hardware assistants a gimmick, or the beginning of the end for smartphones? Let's find out.

RABBIT R1

MAJOR TECH SPECS

- 2.3-GHz MediaTek P35 MT6765 eight-core SoC
- 2.88-inch touchscreen
- 4GB RAM, 128GB storage
- 8MP stills camera (3,264 x 2,448) with 1080p 24fps video
- Bluetooth 5.0, Wi-Fi with 2.4 GHz + 5 GHz, 4G LTE, GPS
- 1,000mAh battery
- 115g

KEY FINDINGS

- The battery is lithium-polymer, clocking 1,000mAh. A bigger one is needed, given how fast it goes through a charge.
- The main housing contains a large motor and gear combo that powers the swivel mechanism on the R1's camera. Attached is the camera sensor and Hall Effect sensor.
- The camera, LCD panel, and small components run by the mainboard. Everything AI-based is on the cloud. There isn't enough processing power for a local LAM or LLM.

HUMANE AI PIN

MAJOR TECH SPECS

- 2.1-GHz Octa-core Qualcomm Snapdragon SoC
- 720p monochrome laser projector, 7cm by 9.6cm display at 30cm projection distance
- 4GB RAM, 32GB eMMC storage
- 13MP stills camera (4,160 x 3,120) with 1080p 30fps video
- Bluetooth 5.1, Wi-Fi 5 (802.11ac) with 2.4GHz + 5GHz, MIMO LTE, plus GPS, GLONASS, Galileo
- 1x internal battery, 2x booster batteries
- 54.7g (with battery booster)

KEY FINDINGS

- The back cover is essentially a charging coil wrapped in plastic, but what really stands out is the level of care that has gone into beautifying the interior.
- The MEMS laser projector uses two piezoelectric mirrors in a galvo configuration, reflecting light off two perpendicular mirrors that rotate slightly. There are two mirrors for the X or Y dimension, which change the laser location.
- The mirrors are nicknamed Castor (Circular) and Pollux (Rectangular). Castor moves back and forth at a set frequency, while Pollux is quasi-static and can be precisely positioned. To display an image, a laser shines and reflects off the resonant mirror to create horizontal scanlines, then reflects off the quasi-static mirror.
- The mainboard powers the local hardware. The LLM is based in the cloud and only accessible via Wi-Fi or cellular.

CONCLUSION

As with any first-generation device category, we don't have anything to compare the Rabbit R1 or Humane AI Pin to, so we're not going to score either of these devices. We hope that any future iteration of similar devices will provide easier access to their respective batteries. But for now, let's just admire the things that Humane and Rabbit did right, cringe at its shortcomings (like awful battery life), and wait to see how this new class of hardware evolves.

Edit your photos in Luminar Neo

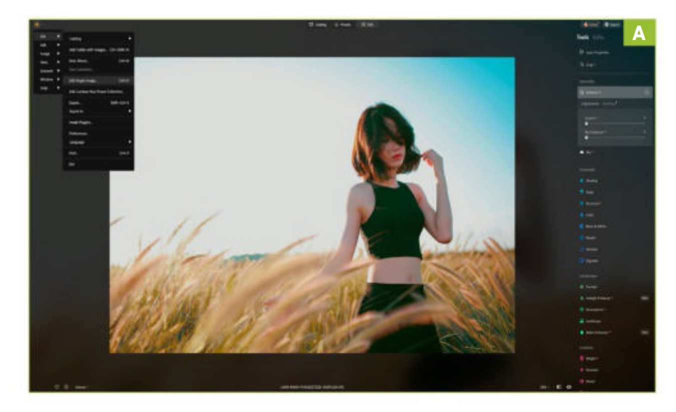
YOU'LL NEED THIS

LUMINAR NEO
Some image files

MANY IMAGE EDITING APPS have been jumping on the AI bandwagon, but for Luminar, it was less of a leap. The app, from Ukraine-founded (but now New York-based) Skylum Software, was already heavily algorithmic, notable for its ability to easily replace skies in photos, as well as providing the sharpening and color adjustments you'll find in many raster image editors.

The app has gone through a few name updates since its inception, and now goes by Luminar Neo, but things have moved on since we last touched on it in 2022. It's available as a standalone app, and as a plugin for Adobe Photoshop (including Elements) and Lightroom. One thing it's very good at is spreading its processing load across all the cores available to it, including the GPU. This means its performance is excellent, and its non-destructive approach to image editing means edits can easily be rolled back if necessary.

It's easy enough to install, and comes with a free trial if you provide your email address. Here are some of the things you can do using the newly added features. –IAN EVENDEN


A

1 GET THE APP

Luminar is easy to install—it's just a case of downloading the installer file from https://skylum.com/luminar-trial for the free demo version. There are a couple ways to pay for it if you like it—a one-off lifetime payment or various subscription plans—but the seven-day trial should be enough for you to work out if it's an app that you want to pay for.

» There's little that Luminar can do that you couldn't achieve in Photoshop, but Luminar's secret sauce is to make it all smoother, easier to approach, and hides all its technical workings behind a minimal interface.

2 GET STARTED

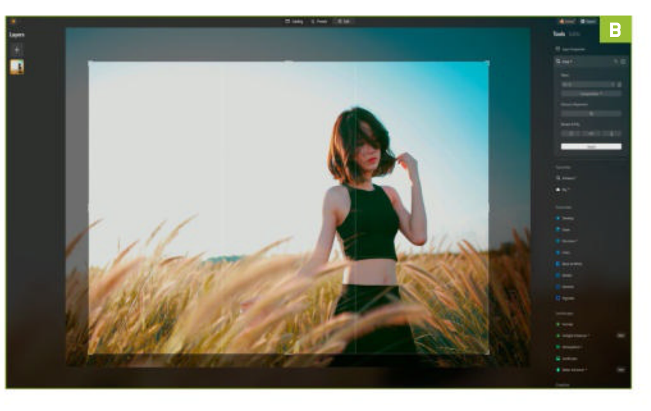
There are a couple of ways to get your images into Luminar. You can add entire folders, including raw images from your camera, or one image at a time. Both of these options are found on the File menu, which is hidden behind the Luminar star logo in the top left-hand corner of the interface [Image A]. As you work on more images in Luminar, they will be added to the Catalog section, which is also found at the top of the interface. You can slip into this at any time, and it's an impressively smooth and fast transition—your work is automatically saved, so you can switch between images at any time.

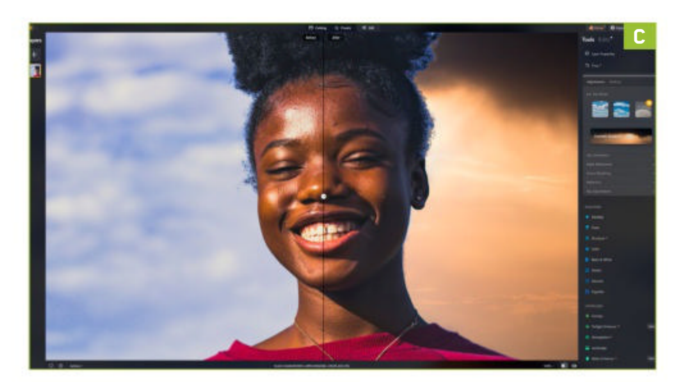
» Once you've settled on an image to work with, one of the first things to look at is the Crop tool. This is a staple of image-editing apps, and allows you to trim away the edges of your photo, altering the aspect ratio and the composition. Luminar has introduced an 'AI' version of the tool that attempts to choose a pleasing composition for you. In our experience, [Image B] it's capable of doing this, placing the subject in this image nicely according to the rule of thirds, but in other image we tried, it seemed to get confused, placing one subject's face down into the bottom right corner of the image, preferring to make the clouds that made up the background the centerpiece of the composition.

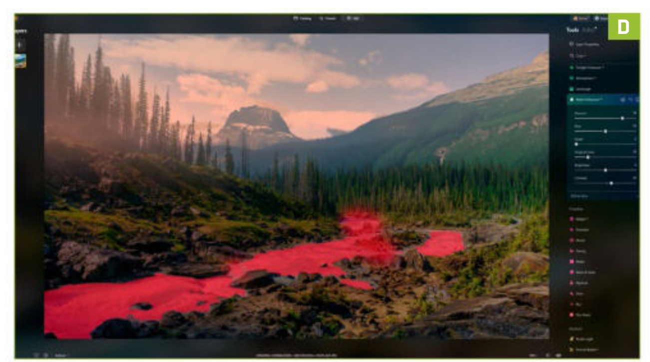
» Before you can do any of this, however, you'll need to find the tools—Luminar likes to open with its Presets to the fore, encouraging you to enter its marketplace and spend money. To enter the Edit mode, you'll need to click the Edit button at the top.

3 ENHANCEMENTS

The Crop tool is at the top of the Edit toolbar, but there's plenty underneath. The AI tools are distinguished by a little 'AI' icon in superscript to their right, and the first of these on the list is Enhance. It's not a new tool for Luminar, but the AI implementation brings a fresh twist. Essentially, it's content-aware sharpening with contrast and saturation tweaks, and by default it's applied to the entire image. There's a Masking tab, however, and this is where the new AI smarts are applied. You can automatically select the subject or background of an image just by hovering your mouse pointer over them, and add and subtract from the selection, too.


B





» Once you've got your selection, you can move the Enhancement slider and see what it does—there's only one, so you don't get much control over the changes it makes apart from how strong they are.

4 SKIES

One thing Luminar is famous for is its ability to replace the sky in an image. Photoshop can do it now too, but for a while this was purely Skylum's area of expertise. Sky is the next choice on the Edit sidebar list, and you get a lot more options. There's a masking tab here too, and while it's generally fine, we found that, like many automatic tools, it was unable to cope with fuzzy edges, such as the interface between hair and the background [Image C], so using a manual tool, such as a brush or gradient, or the refinement sliders, on these will give you a better result. A new addition to this section is a Luminance mask, which allows you to select only the bright or dark parts of an image. This is particularly useful for skies.

» Once you've told the app what part of the image is the sky, or allowed it to make up its own mind, you can select from a list of new skies or upload your own, and they will be inserted into the composition. From there, you can move back to the Adjustments panel and play with the lighting of the scene. The three Scene Relighting sliders affect the brightness and color in the image. The first two, Strength and Saturation, affect the whole image, but mostly the background, while the third, Relight Human, picks out any people in the photo. There are also adjustments that can be made to the sky, whether you've replaced it or not, allowing you to throw the clouds out of focus or add an atmospheric haze effect, as well as tweaking the brightness and color saturation.

5 ESSENTIALS

The Essentials section of the toolbar contains tools that you'll be familiar with from other image-editing apps. There's little new here, but the ability to increase or decrease exposure and contrast across the whole image, or selectively alter the highlights and shadows, is always useful when you're touching up photos.

» There is an AI tool here in the form of Structure, though the AI influence is once again only felt in the masking, where it can select the photo's subject with all the usual caveats about soft edges. In our testing, it couldn't manage the border between hair and sky, and even missed a fairly strong boundary between the side of a face and the background. Structure is a detail-enhancing tool that will bring out the texture of skin, but begins with the slider halfway along, so it can be pulled back to soften details and produce a less harsh—and often more flattering—look.

6 THE TWILIGHT ZONE

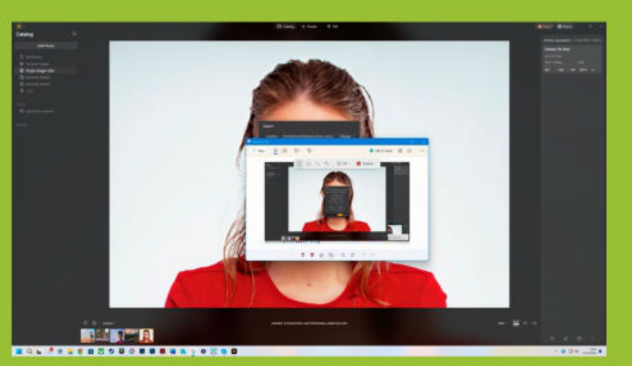
If your tastes run more toward landscape images, there's something for you in Luminar alongside all the portrait effects. The app's AI-powered masking can recognize elements such as trees, water, or mountains in an image, and select them at the press of a button, so you can work on them separate from the rest of the image.

» Top of the list is the Twilight Enhancer, which has the same AI-powered masking that works a bit better

NON-DESTRUCTIVE EDITING AND EXPORTING

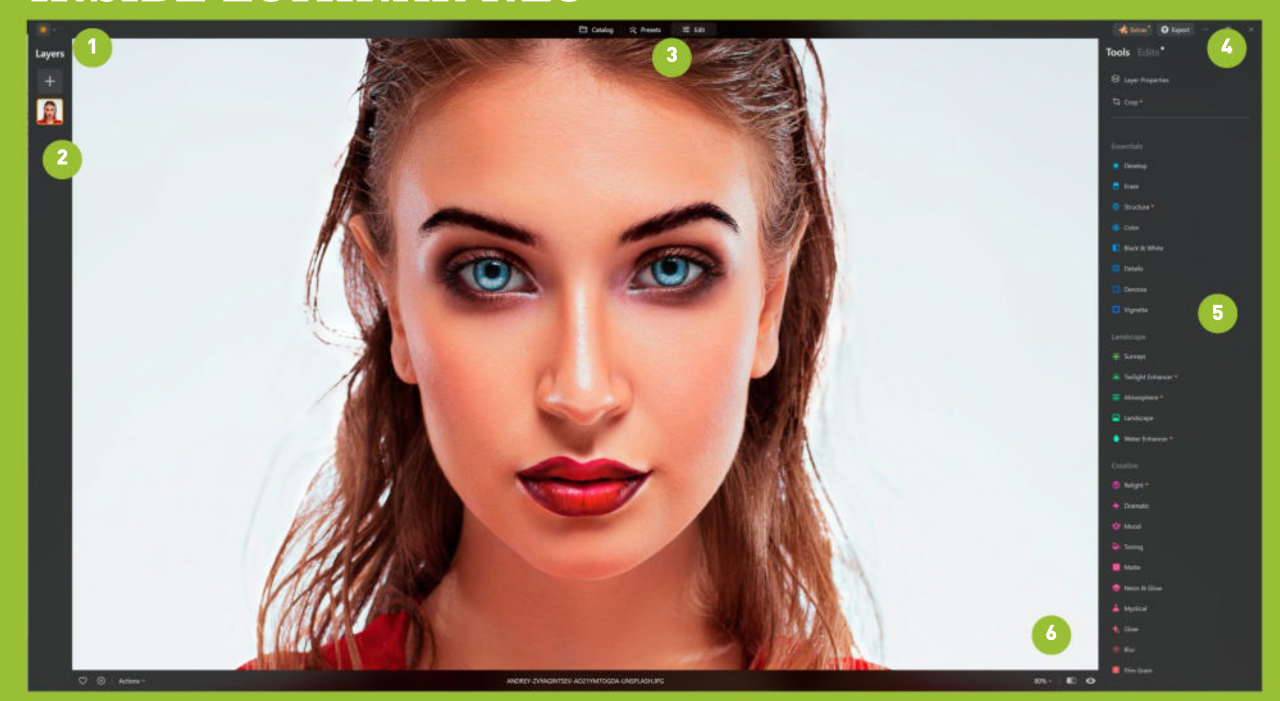
Luminar is a non-destructive editor, which means your original file is kept safe, and edits are only applied to a new file that you export at the end of your session. The app makes it easy to export an image, with a button at the top of the interface presenting a pop-up box with plenty of options, allowing you to specify the file format (including PSD and PDF) pixel dimensions and color space (sRGB, Adobe RGB, or ProPhoto RGB) of your final image. There are options in the Crop tool to the correct size for Facebook cover and feed images, but for other social networks, check what the best sizes are before cropping and exporting.

Not only can you save to a local folder on your PC; it's possible to send an image to a mobile device through Luminar Share, an app for mobile devices. This is useful if you use Instagram, as that service's desktop



PC support is poor, and also means you can send image files the other way, taking a photo with your smartphone and sending it to Luminar for editing.

INSIDE LUMINAR NEO



1. MAIN MENU
Kept very small and in the corner, this is where you'll find File, Edit, and all that sort of thing.

2. LAYERS
This is used for putting overlays, such as light leaks and other effects, over your images while maintaining control.

3. MODES
This is where you switch between the Presets and the Editing tools, or open the Catalog in order to quickly swap to another file.

4. EXPORT
Luminar is non-destructive, so doesn't overwrite your original file. Export your work as a new file from here.

5. THE TOOLS
A list of tools, each with sub-divisions and usually multiple sliders. They can be collapsed to keep things tidy.

6. VIEWS
Two buttons to quickly remind yourself of the original image, or to bring up a divider for before and after comparisons.

on the sharp delineations between mountains, trees, and skies. There are plenty of tools—some, such as the Twilight Enhancer, will add a color cast to your image that can simulate shooting at sunset (the Golden setting), dawn (Blue), and all sorts of colors in between, while others are designed to only affect the sky, or water. There's an Atmosphere slider that adds a haze, and you can control how it interacts with the objects in your image, while the AI Water Enhancer [Image D] can pick out the wet bits and alter their color and brightness, though it sometimes needs a little help in the parts where water passes across rocks.

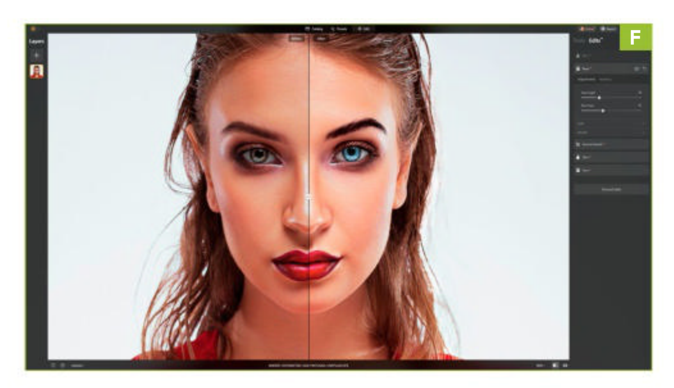


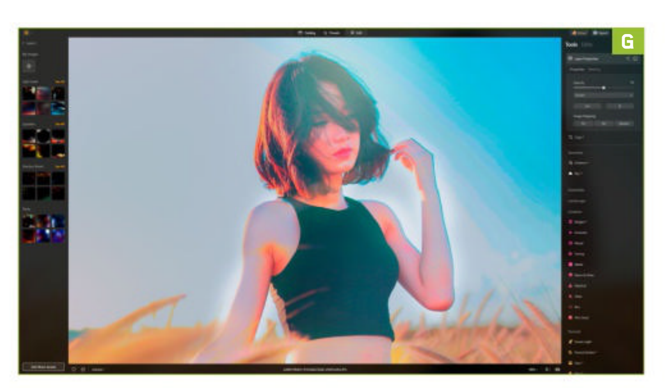
7 THE CREATIVE ZONE

The next set of tools are merely labeled 'creative', which really should apply to the entire app. These options are essentially one-shot filters in that they can be applied to the whole image, or masked, and their strength adjusted, but there aren't always lots of options for changing how they look. A good example of this is Dramatic, a contrast and saturation boost that has two sliders: Amount and Local Contrast. The next tool on the list, Mood, offers more control, as it applies Look Up Tables (LUTs) to the image that can change the appearance of your photo quickly and consistently [Image E]. From the Mood menus, you can find film simulation looks, or cross-processing effects that can be applied with a few clicks to multiple images, speeding up your workflow if you find yourself making the same changes regularly. The ability to use your own LUTs makes this especially powerful if you have a lot of files.

8 PORTRAITS

The Portrait section of the toolbar offers more new AI capabilities, but also offers tools that skirt the boundaries of what's acceptable in photo editing. There are lighting tools that can make a big difference to





the look of a photo, but also options that can enlarge, reduce, or 'enhance' particular body parts, particularly in the face. Editing photos in this way is nothing new, and many magazine cover images bear little relation to reality, but tools like this do raise the question over whether it's right to digitally reshape someone. The facial tools [**Image F**] pay particular attention to the eyes, enabling you to change their color and increase the visibility of the iris, as well as increasing the size of the whole eye and whitening them. There are some more general 'enhancer' tools, one of which will sharpen and darken eyebrows, and another that can brighten and soften skin, plus remove what it calls 'defects'. Are they really defects, or do they just make a face more interesting? That's a long-running debate. It's worth noting that the Slim Face slider starts at zero, meaning there's no option to go backwards and actually make a face wider, which possibly says something about modern beauty standards.

» The ability of Luminar to slim and 'enhance' a face is also available for the rest of the body. Under Body you're presented with two sliders, one for Shape and the other for Abdomen, plus the usual masking to make sure you're applying the changes to the right part of the image. Shape is effective across the whole body, and allows you to widen or narrow it, while Abdomen is mainly applied around the stomach and hips. It's a very easy tool with which to make something that looks unnatural and comical, so is best applied sparingly, if at all.

9 MORE TOOLS

Underneath the Portrait section sits a group of tools marked as Professional, perhaps suggesting they're not for casual users. In fact, there are some digital darkroom tools that will be familiar if you've used Photoshop, including dodge and burn brushes to selectively lighten and darken sections of your image, as well as contrast sliders and a Color Harmony section that changes the way the various colors of your image mix and interact. This section feels more analog than the rest of the app, but despite this, it allows you a greater degree of control over the final look of your image. It's ideal for finishing off when the more automatic tools above haven't quite produced the look you want, and thanks to the way Luminar works, this means you can produce multiple versions of an image quickly. There's also a Clone Stamp tool, which you can use to paint over sections of the image you'd like to remove in much the same way as Adobe's version.

10 LAYERS

In common with a lot of image-editing apps, Luminar supports layers, which divide your image into vertical slices that can be stacked, blended, and otherwise forced to interact in interesting ways. The Layers palette is on the other side of the interface from the Tools, and consists of a number of graphical effects that can be stacked over the top of your image, including some that you can add yourself or purchase from the Luminar store [**Image G**]. Each layer can have its opacity and blend mode altered, and masks can be used to control where it is visible over the main image. They can also be dragged around so that the order in which they appear is changed, and it's possible to flip and stretch them so they better fit your composition.

PRESETS

Luminar's selection of presets are one-shot filters that can be quickly applied to an image. There are plenty included with the app, covering everything from high-contrast monochrome portraits to cinematic film looks, and some appropriate for soft landscapes. Clicking through them takes little time, and they are instantly applied to your image as a preview just from hovering your pointer over them. Each is applied at 100 percent strength, and comes with a slider you can use to back off the intensity. These presets are customizable, and you can create your own from edits you've made using the Actions menu at the bottom left of the interface. These can also be shared with other Luminar users, or backed up if you're changing computers.

If you feel that you need more, there's a whole store full of additional skies,



filters, layer effects, LUTs, and extensions such as AI upscaling, noise removal, or focus-stacking. Many of these are available as bundles, though Luminar is highly extensible, and its ability to tie into the Creative Cloud apps as a plugin means that it's easy to integrate into an existing workflow.

Master LibreOffice 24

YOU'LL NEED THIS

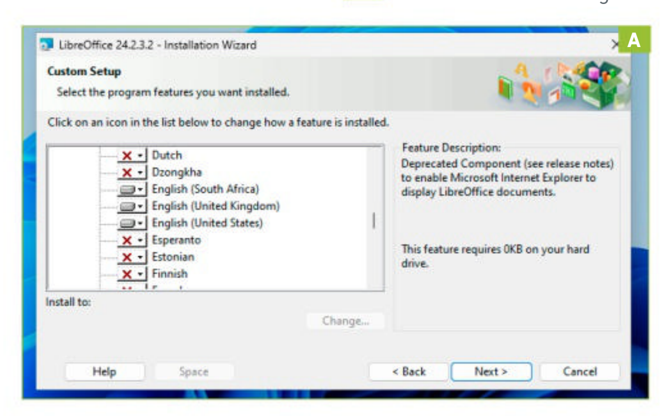
A RECENT INSTALL OF LIBREOFFICE 24.2
Java Runtime Environment (For certain Base features)

LIBREOFFICE BEGAN its life in 2010 as a fork of OpenOffice.org, which was itself an open-source fork of StarOffice. This productivity suite is developed and maintained by TDF (The Document Foundation), which remains loyal to its open-source roots. This means that unlike Microsoft Office, LibreOffice is cross platform as ports exist for Windows, macOS, and Linux.

The suite consists of a word processor (Writer), spreadsheet software (Calc), presentation program (Impress), a vector graphics editor (Draw), an application for editing mathematical formulae (Math), and a database management program (Base). LibreOffice defaults to the OpenDocument Format when saving files, but can also open, edit, and save Microsoft formats like Microsoft Word (.docx).

The most recent release of LibreOffice (24.2.3) was made available in early May, and comes with some promising new features. While TDF doesn't seek to emulate Microsoft Office exactly, LibreOffice does have very similar functionality, with the exception of offering a free online version in the vein of Office 365. Self-hosted solutions are available for 'LibreOffice online' for those with the time and patience to set up the suite on their own server.

In this tutorial, we'll discuss the basics of setting up and customizing your LibreOffice install, as well as becoming familiar with the user interface of the principal apps. **–NATE DRAKE**



1 CUSTOMIZE YOUR INSTALL

Setting up LibreOffice is a case of pointing your browser to https://libreoffice.org and clicking 'Download'. The installer is available for both 32-bit and 64-bit Windows systems.

» Sharp-eyed readers will see that there are in fact two versions for download. LibreOffice 24.2.x is the focus of this tutorial, and contains all the latest features. However, you can also download LibreOffice 7.6.7. This version is older, but has the benefit of being more stable due to the longer testing period.

» The default download is for the US English version of Office. If you want another language or regional variation, such as British English, click 'Need Another Language?' to download the relevant installer. [Image A]

» If you need LibreOffice to support multiple languages, during the install process change the setup type from 'Typical' to 'Custom'. Now, you can install features like language packs.

» The custom install is divided into two main sections: 'Optional Components' and 'User Interface Languages'. If you're happy with the default interface language and just want to install extra language dictionaries, expand 'Optional Components' > 'Dictionaries'. By default, LibreOffice installs dictionaries for English, French, and Spanish.

» Take the time to explore other optional features by clicking on each and reading the feature description. If it's not enabled already, as a minimum we recommend installing the 'Windows Explorer Extension', which enables File Explorer to display key information about LibreOffice documents, display thumbnails, and make the text searchable.

» If you require the LibreOffice interface itself to be available in multiple languages, expand 'User Interface Language' to install the packs of your choice. By default, the English version of LibreOffice supports US, British, and South African English.

2 LAUNCH YOUR LIBREOFFICE APPS

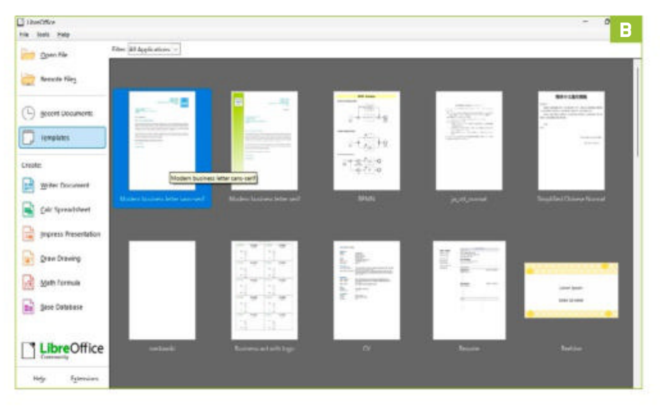
Once the install process is complete, open LibreOffice via the shortcut on the desktop.

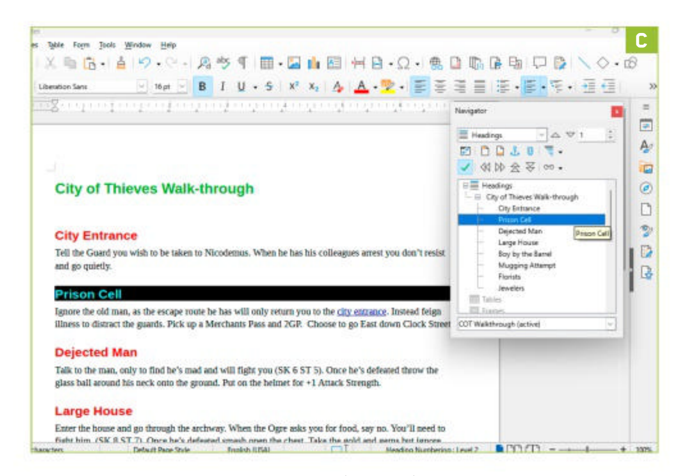
» The main window works in a similar way to Microsoft 365's App Launcher in that you can use it to open existing files or create new LibreOffice apps.

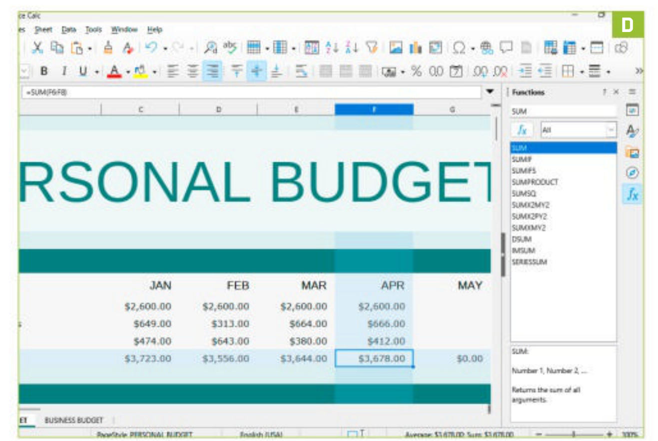
» This is a good chance to get used to the naming conventions for LibreOffice apps. 'Writer' is used for word processing, while 'Calc' is an excellent spreadsheet program. 'Impress' can be used to create presentations in the vein of Powerpoint, while Base is broadly equivalent to Microsoft Access in that it can be used to create and edit databases.

» Click on 'Templates' [Image B] to view some sample LibreOffice documents. Use the 'filter' drop-down menu at the top left to narrow templates down to specific apps like Writer.

» Double-click to open the very first of these, which is a template for a business letter. Once Writer launches, choose 'Release Notes' at the top right. This will launch your default browser, allowing you to learn all that's new in the latest version of LibreOffice.







» Once you've done this, click 'File' > 'Save As' from the top left menu. Once the save dialog opens, you'll note that under 'Save As Type', Writer defaults to its native OpenDocument Format (.odt). Using this format means your documents will have the best level of compatibility with LibreOffice features.

» However, sending documents in LibreOffice format can sometimes cause issues for Microsoft Office users. While Office nominally supports the OpenDocument Format, files that you send to users may not display correctly.

» Fortunately, there's an easy fix. Just click the 'Save as Type' drop-down menu, and choose 'Word 2010-365 document'. This will save the document in .docx format.

» If you want LibreOffice to default to saving in Microsoft Formats, go to 'Tools' > 'Options'. In the new window, expand the 'Load/Save' section, and select 'General'.

» In the section on the right, choose the drop-down menu 'Always Save As', and select your chosen format. Change 'Document Type' to do this for other LibreOffice apps.

3 WORKING WITH WRITER

LibreOffice Writer is the suite's answer to Microsoft Word in that you can create and edit text documents of all kinds.

» Although the interface has received online criticism for being 'traditional', it's very simple to navigate.

» If you're starting out with Writer, first make sure to visit the dedicated help page (https://help.libreoffice.org/latest/en-US/text/swriter/main0000.html) for a full rundown of all features.

» The current document spelling/grammar language is displayed in the bottom pane, e.g. English (USA). To change this, right-click and select 'More'. In the new 'Character' window, select the 'Language' drop-down menu to switch to a different dictionary, then choose 'OK'. Your chosen language will appear on the bottom pane. You can also manually initiate a spell check by choosing F7.

» Unlike Microsoft Office, LibreOffice documents aren't automatically saved with your personal details. To change this, go to 'Tools' > 'Options'. From here, expand 'LibreOffice', and choose 'User Data'. Enter your personal details in the right hand pane, then click 'Apply'.

» Entering your personal information in this way lets you make full use of the 'Comments' feature. Simply highlight any section of text and use Ctrl + Shift + C to add a comment. Writer will display your name and the timestamp for each one. In LibreOffice 24.2, comments can also now use Styles. Access the 'Styles' menu to view options to edit font, size, and formatting.

» Press F5 at any time to open the Navigator window. This allows you to easily navigate different sections of the Writer document. The best way to see this in action is to click the 'Default Paragraph Style' drop-down menu at the top left of the Writer window [Image C], then choose one of the headings.

» As you add more sections, they will appear in the Navigator window, along with objects like hyperlinks.

4 BE CRAFTY WITH CALC

As with Writer, Calc has a help page on the main LibreOffice website (https://help.libreoffice.org/latest/en-US/text/scalc/main0000.html?DbPAR=CALC) with an introductory video and a list of all Calc features.

» We do recommend reading through this. While Writer can be picked up easily by anyone with a passing

LIBREOFFICE ONLINE

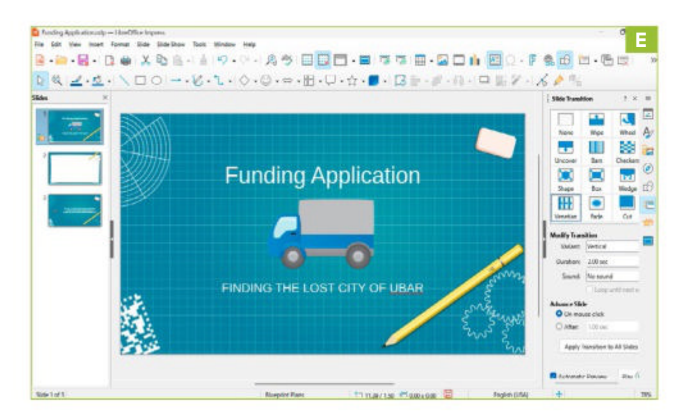
The existence of online office suites like Google Docs and Office365, can make offline software seem quaint. Of course, this can also be a strength if you're in an area with patchy internet connection, but there's something to be said for knowing all your documents are stored safely in the cloud.

LibreOffice online offers a solution in the form of server software built using the suite's source code. Bad news first: LibreOffice don't offer the online version on their own servers, so you'll need to self-host to make use of it.

On its website, The Document Foundation explains that LibreOffice Online doesn't include a file system, which is necessary for accessing files and authorizing users. It's also missing any load balancing tools or features that would need to be developed for a viable online version of the suite.

At the time of writing, TDF has frozen the LibreOffice online repository, though the code is freely available. The current version is designed for personal use only, so you'll see an 'unsupported' notification if you open 10 concurrent documents and/or 20 simultaneous connections.

Compiled LibreOffice online packages are available via Collabora and the suite can also be installed via Docker Images. Visit https://www.libreoffice.org/download/libreoffice-online to discover more.



familiarity with Microsoft Word, Calc is less intuitive. Although it can replicate most Excel features, these are usually accessed in a slightly different way.

» LibreOffice 24's Calc now includes a new search field in the 'Functions' sidebar. To access this, click the dedicated button in the right-hand pane, or hold down Alt + 5.

» From here, you can enter a function into the search bar at the top, eg. 'SUM' [Image D], then double-click the corresponding function in the pane below to enter the full formula.

» As with most spreadsheet programs, when you click on a cell, the corresponding row number, e.g. 9, and column, eg F, are highlighted. If you still find this hard to follow, the latest version of LibreOffice also now supports highlighting the entire row or column each time you click on a cell. To enable this feature from Calc, go to 'View' > 'Column/Row Highlighting'.

» You can also use the 'View' menu to choose 'Show Formula'. As the name suggests, this will display actual formulae used in sheets. LibreOffice 24 now supports copy and pasting of formula directly. In other words, once 'Show Formula' is enabled, if a cell's contents are pasted into a plain text editor, the formula will appear, not its result. You can also paste formulae into Writer via 'Edit' > 'Paste Special' > Unformatted Text.

» If you're working with multiple spreadsheet tabs, Calc now handles cycling through them a little more intuitively by going from last to first. Use Ctrl + Tab to switch sheets.

5 INNOVATE WITH IMPRESS

Although you can go to https://help.libreoffice.org to view the comprehensive help guide for Impress, we feel readers may not need this, as the interface is very intuitive.

» Upon loading, Impress shows the current slide in the main pane. The sidebar on the left lists all available slides. You can click into these [Image E] or right click inside the sidebar to add a 'New Slide'.

» The right-hand pane displays slide 'Properties'. From here, you can make changes to fonts, text color, spacing, and so on.

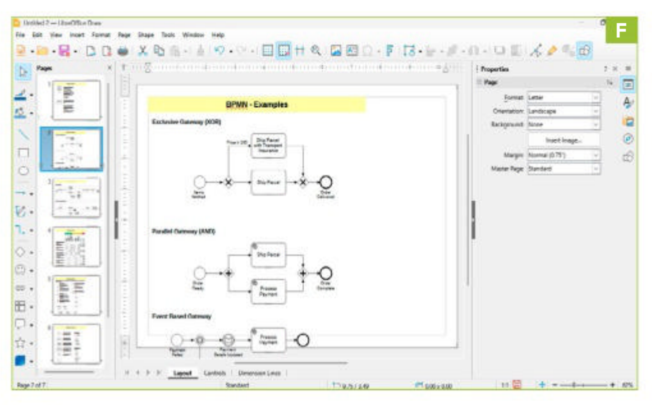
» If you're fond of adding 'clipart' to slides, you can view Impress's offline offerings at 'Insert' > 'Media' > 'Gallery'. There are some shapes and icons, but if you want more, click the button at the bottom right to 'Add More Galleries by Extension'.

» Scroll through the gallery sets, then click 'Install' next to any you want made available when using Impress. During our tests, we found that in order to view the newly installed Clipart, users must close and reopen Impress after installing extensions.

» Aligning slide objects works in a very similar way to Powerpoint: simply click and drag or hold shift to select multiple objects, then right-click. From here, you can access the 'Align' option, e.g. to align the centers of text boxes and images.

» If you want to use animation when switching between slides, choose 'View' > 'Slide Transitions'. Various transitions will now appear in the right-hand pane. Click on each of these to preview the effect. Click the button at the bottom of the pane to 'Apply [this] Transition to All Slides'.

» To configure more global options, go to 'Slide Show' > 'Slide Show Settings'. This allows to enable options like animated images, remote control support and the presentation mode, e.g. fullscreen.



6 DOWN WITH DRAW

Draw is a vector graphics editor. It's particularly good for making flowcharts and technical drawings, though it can also be used to design media like posters and brochures. It's also an excellent tool for editing PDFs. [Image F]

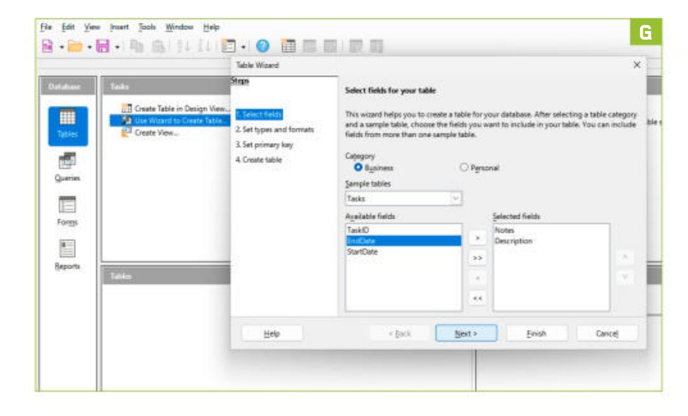
» This app is notable in that it has no obvious equivalent Microsoft Office app, though Draw can open Microsoft Publisher (.pub) files. By default, files are saved in the Open Document Format (.odg).

» If you've never used 'Draw', repeat the instructions in Step 1 to access the LibreOffice App launcher and open the template flowchart. As you'll see, the current page is always featured in the center of the window.

» The left-hand pane allows you to scroll through current 'Pages'. Use right-click to add 'New' or 'Delete'.

» By default, the right-hand pane shows the current page properties, such as the font and spacing, though as with Impress, this can change depending on the specific feature you're using. For instance, if you wish to add images from the media gallery via 'Insert', the pane will change accordingly.

» The current version of Draw hasn't changed much, though the release notes mention that multi-page TIFF images are now supported. If you add a picture in this format (via 'Insert' > 'Image'), Draw will place one image on each page.



MASTER THE LIBREOFFICE LAUNCHER

1. OPEN FILES
Click here to locate office documents on your system. LibreOffice supports both the OpenDocument Format (ODF) files and Microsoft Office documents. Choose 'Remote Files' to open documents stored on servers.

2. FILTER APPLICATIONS
If you're working with a large number of documents, use this drop-down menu to display only files of a specific type, eg. Presentations. This also works when browsing templates.

3. ECENT DOCUMENTS
Click here to view all files (both local and remote) that you've opened recently in the main pane. You can also click the settings (three bars) at the top right to clear the log of recent documents.

4. TEMPLATES
LibreOffice comes with a small number of templates for Writer, Draw, and Impress. If you can't find what you need, visit https://extensions.libreoffice.org, and click into the 'Templates' subcategory to download more.

5. CREATE DOCUMENT
Use this section to create a new, blank document in the LibreOffice app. By default, the document will save to ODF format, but you can configure applications to save in Office formats.

6. EXTENSIONS
Click here to explore LibreOffice extensions in your browser from https://extensions.libreoffice.org. You can also install extensions from within the apps. For instance, Impress supports downloading additional image galleries.

7 ADDICTED TO BASE

In theory, Base is an excellent app for opening, viewing, and editing databases. Users can work with tables, queries, forms, and reports, much like Microsoft Access.

» In practice, it's best to check the online documentation first to make sure it's compatible with your existing database (https://help.libreoffice.org/latest/en-US/text/sdatabase/main.html).

» We say this, as some database types are read-only in Base, such as spreadsheet files, text files, and address book data.

» If you don't have any existing files then upon opening, Base will launch its 'Database Wizard'. From here, you can create a new embedded database in HSQLDB format. Base also supports acting as a frontend to a variety of external types of database like MySQL/MariaDB, PostgreSQL, Microsoft Access, and JDBC.

» Assuming you proceed to create a new embedded database, you have the option of choosing to register it with LibreOffice. By default, once you click 'Finish', the database can be opened for editing, though you can check 'Create Tables using the Table Wizard'.

» This is an excellent and intuitive way to create database tables, but in order for this feature to work, you'll need to have JRE (Java Runtime Environment) installed. Make sure to choose the correct JRE for your architecture, e.g. 64-bit.

» Once this is done, the Table Wizard allows you to choose from two broad categories [Image G]: 'Business' or 'Personal'. You can also choose from a number of 'Sample Tables', such as 'Tasks', 'Events', and 'Employees'.

» Each of these have their own sample 'Available Fields', e.g. 'StartDate'. You can add these to your own table by clicking on the corresponding entry, then on the relevant button to list under 'Selected Fields'.

» You can use the 'View' menu to switch between tables, queries, forms, and reports, or just click on the corresponding icon in the left-hand pane. In each case, you can use a wizard or 'design view' to create your data set.

Use your tablet as a second PC monitor

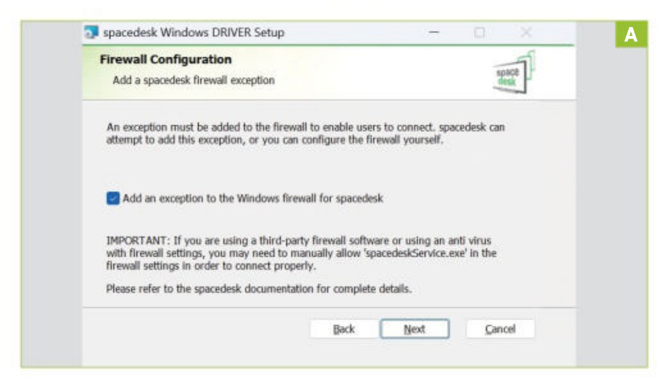
YOU'LL NEED THIS

SPACEDESK
Download the PC software from spacedesk.net

WHAT DO YOU DO IF YOUR MONITOR feels a bit cramped, but you don't want to pay for a bigger one? Or need to keep an eye on a website or video stream? Fortunately, if you have a tablet or smartphone going spare, you can expand your desktop space without spending a penny.

Spacedesk can turn your unused phone or tablet into an extension of your computer screen. It does this with two programs: one that sends images to your tablet or phone from Windows, and one on your mobile device that makes it behave like a connected monitor.

It works by making Windows think the remote device has a physical connection. That way, you can drag program windows on to your device's screen and work on them as you would on your primary display. We'll refer to tablets in these instructions because the bigger screen makes them more suitable as monitors, but our steps work the same for phones. –NIK RAWLINSON



1 INSTALL SPACEDESK ON YOUR PC

Start by downloading Spacedesk's PC software from spacedesk.net, where you'll find options for 64-bit and 32-bit Windows in the section called 'Spacedesk Driver Software for Windows Primary PC (server)'. Most modern PCs will need the 64-bit version, but if you're not sure, open Settings by pressing Windows key+I, then click System followed by About, and check the version beside 'System type'.

» Click through the installation instructions and, when you reach the Firewall Configuration page, leave the box ticked beside 'Add an exception to the Windows firewall for spacedesk' [Image A]. If you disable this, connections between your PC and your tablet will be blocked, and you won't be able to use the device as an extension of your main PC screen.

» When you've completed the last screen of the instructions, it will proceed with the installation. This throws up a User Account Control alert asking if you're happy for the program to make changes to your PC. On our machine, this alert was minimized in the taskbar, so it wasn't easy to spot, and gave the impression that the process had stalled. Keep an eye on your taskbar in case this happens. Once installation has completed, click Finish.

2 INSTALL SPACEDESK ON YOUR TABLET

Download the app on your tablet from tinyurl.com/3td8cc89 (Android); tinyurl.com/327psdec (iOS, iPadOS); or tinyurl.com/w23dbadv (Kindle Fire), then launch it. If you've installed the program on your PC, dismiss the message telling you to download it.

» The app will now start searching your local network for your PC and, when it recognizes it, display its IP address. It's made up of four sets of digits, with the first three generally being the same across the whole network, while the final set will be anything between 0 and 254 (to accommodate a maximum of 255 devices on your network).

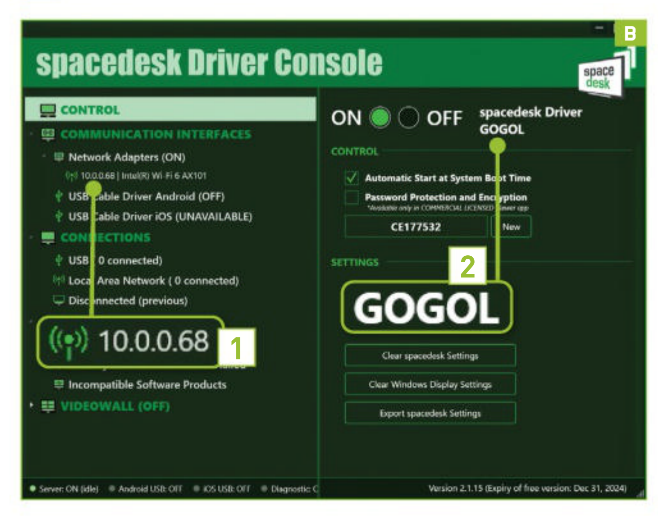
» Our tablet found a PC using the IP address 10.0.0.68. We checked this was correct by comparing it to the information shown in the Spacedesk Driver Console software that we installed on Windows. You can launch this from the Start menu and, when it appears, check the address in the Communication Interfaces section. In [Image B], we can see the same IP address: 10.0.0.68 1.

» To double-check, we make sure our computer's name (GOGOL 2) is displayed at the top of the right-hand column in Driver Console, as well as at the top of the home screen on the Spacedesk app on our tablet.

3 MOVE WINDOWS TO YOUR TABLET

Tap the computer's address in the app, and the devices will connect, your tablet's display behaving like a touch-sensitive extension of your screen.

» You can now drag windows from your PC to your tablet. However, because Spacedesk can't automatically work out where your tablet is sitting in relation to your computer screen, you may need a little trial and error. We found that dragging windows to the right of our main



display, slightly above halfway, transferred them to the tablet's screen, even though our tablet was to our left, flat on its back.

» Once the window is on your tablet's screen, control it by clicking with the mouse or tapping it with your finger. If you want to use your fingers on the tablet and your mouse and keyboard to control your computer, you don't need to make more changes, as long as you're happy with how the screens are configured.

4 RECONFIGURE YOUR SCREENS

If you want to move your cursor off the edge of the main screen nearest to your tablet screen so that it travels toward it, tell Windows where they sit in relation to one another. This makes working easier when sweeping the cursor off your PC's screen and back again.

» To do this, click the up-arrow on your Windows taskbar to reveal your hidden icons, then right-click the Spacedesk driver icon, followed by 'Windows Display Control Panel'.

» This will take you to the Display pages of the Windows Settings program, where you'll see a graphic of your screens. The larger one, [Image C] labeled 1, 1 is your PC screen. The smaller screen 2 in the top-right corner (labeled 2) is your tablet.

» If this is less clear in your setup, you can ask Windows to identify each one. Click the Identify button, 3 and it will display the relevant numbers in the corner of each display.

» Use your mouse to click and hold the number 2 (tablet) box in the Settings window, then drag it around the number 1 box. Let go when its location roughly equates to your tablet's position relative to your PC screen. When you've finished, close Settings.

» You're not restricted to just one external tablet, nor to working with tablets. We installed Spacedesk on an iPad Pro, Kindle Fire 8 tablet, Google Pixel 5 phone, and iPhone 15 Pro, and set them all running simultaneously.

» You can see the result in [Image D], where our primary monitor is surrounded by four smaller screens. This allowed us to move our cursor and program windows from one to the other.

5 USE PROGRAMS ON YOUR SECOND SCREEN

Now that you're set up, you can use your second screen as a place to put programs that might get in your way.

» If you prefer not to use your finger to control a program on your tablet screen, you can use your mouse. Your PC's keyboard will work just as well in any program on the second screen—just make sure the program is active and selected.

» Spacedesk also has its own on-screen keyboard—you'll find it by tapping the three-line menu button on the tablet screen, followed by Keyboard (you can move this menu around by tapping, holding, and dragging it to any position you want). However, using the on-screen keyboard in wireless mode is a premium-only feature, which requires an upgrade to the commercial business licence on an Android device for an additional fee.



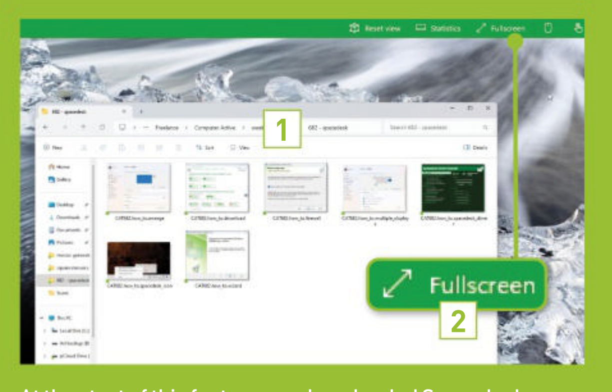


» Spacedesk hasn't yet added this licence to the iPad, iPhone, or Kindle Fire editions of the software, although you can use the keyboard for free on Android or Kindle Fire by connecting via USB rather than wirelessly.

» If you do connect with USB, open the Spacedesk Driver Console software on your PC and click the Communication Interfaces header. Now, untick the box beside Local Area Network, and click in the box below it.

» When the connection has refreshed, tap the three-line menu button on your device, then tap Keyboard. Tap within the window of your active program, and you can use the on-screen keyboard in place of the keyboard attached to your PC.

USE AN OLD LAPTOP AS YOUR SECOND



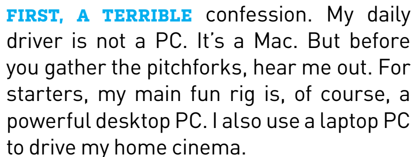
At the start of this feature, we downloaded Spacedesk to our primary PC (or 'server' in Spacedesk terms). This handles the sharing of the virtual display connection with a secondary device (called the 'client'). So far, we've only used a phone and tablet as the client, but you could use an old laptop. Rather than download another copy of the server software to the laptop, go to the Microsoft Store at tinyurl.com/mu7ms2pv and install the client software.

Once launched, it should spot your main PC across your wireless network. Click the primary PC's IP address in the Spacedesk client on your laptop, and the two will connect, with the Windows desktop of your main machine extending into the window now shown on your laptop (1 in our screenshot). Hover over that window, and click the Fullscreen button 2 so it fills the whole display.

LAB NOTES

JEREMY LAIRD, CONTRIBUTOR





Solid state laptops

Portable PCs with moving parts



Want to experience the future of PC laptops? Try a MacBook Air.

FIRST, A TERRIBLE confession. My daily driver is not a PC. It's a Mac. But before you gather the pitchforks, hear me out. For starters, my main fun rig is, of course, a powerful desktop PC. I also use a laptop PC to drive my home cinema.

The Mac really only gets used for web browsing and text editing, plus some casual content creation. But the main reason it's a Mac is because it needs to be portable. I want to be able to pick it off my desk and take it into the office while maintaining its working state. Right now, only Apple offers a truly solid state laptop, or at least one that offers good performance and features as opposed to a glorified tablet PC running Atom cores or something similarly hideous.

I speak, of course, of the MacBook Air with Apple silicon. Once you've lived with a truly solid state laptop, one with not only solid state storage—which has long been the norm—but also no active cooling, fans, or pumps, every other portable seems awfully clunky. It actually makes you wonder how anyone thought it was a good idea to have laptops that screamed under load while they cooked their innards. It's all a little bit silly.

Well, for most mainstream laptops, that could all soon be history. The first Windows laptops using Qualcomm's new Snapdragon X Elite CPU have been released. You'll no doubt see coverage of them in these pages over the coming months. It's yet to be seen just how good the X Elite is, but critically, it uses the same basic Arm CPU architecture that allows Apple silicon laptops to be so efficient.

As far as I know, all of the first X Elite laptops do actually have active cooling. But then, so does a MacBook Pro—it's just it barely ever activates. In any case, the X Elite is just the first of what you might call a new generation of 'proper' Arm chips for PCs. Several other companies, including Nvidia and AMD, are rumored to be working on their own Arm chips for the PC. I'd be amazed if you couldn't buy a totally solid state PC laptop with excellent performance very soon.

Of course, the absolute highest performing portables are always going to use active cooling. My Razer Blade 15 gets so hot just above the keyboard that it can actually burn skin, but that's mostly because of its powerful GPU, something that can't be solved with Arm CPU cores. But I fully expect to be able to have a solid state daily driver PC to replace my MacBook pretty soon.



GUY COCKER

Editor-in-Chief

The upside of building your own PC is the flexibility to create a system to your specifications. The downside is that there's no one to call when things go wrong, which in my experience, they do.

For the last two months, my year-old rig had been crashing about twice a day, and it was impossible to play a game without it stalling. Our resident building expert, Zak Storey, suggested it was down to either my NZXT C1000 power supply or Gigabyte Z790 GAMING X AX motherboard.

In our photo studio, I grabbed a few spare parts to try and diagnose the problem. First, a replacement C1000 PSU was installed into the existing system, but my PC refused to boot.

Frustrated, I looked at motherboard options. Sadly, all I had were older Z690 boards, which would require BIOS updates to support my Intel Core i5-13600K CPU. Firstly, an Asus ROG STRIX Z690-E Gaming WiFi seemed like an easy swap, but it didn't boot either. Next, an EVGA Z690 DARK K|NGP|N, which wouldn't even fit in my NZXT H7 Elite case, thanks to its larger E-ATX form factor.

My final option was an NZXT N7 Z690 mobo, which worked like a charm. True, I had to pair it with older DDR4 RAM, but this has little impact on gaming performance. The main thing is I have a working desktop again, and one I can play games on. Such luxury!



The Eufy L60 Robot Vacuum is a potential life-changer.

Editor's Pick: Eufy L60 Robot Vacuum & Self-Emptying Station

The cleaning revolution is here



AS YOU MAY know from my many ramblings on these pages, I now work as a barista during the day for a local coffee shop, and as a freelance journalist in the evening and on days off (terrible work-life balance, would not recommend). When I started doing this, it took quite a toll. Not only on my fitness and health, but on my home life as well. I'm a massive contributor in the Storey household when it comes to chores. Cooking, cleaning—I do the bulk of it.

Changing jobs and how you work is never easy, and adjusting to that new way of living takes time. I knew this was going to be the case—going into freelance, in fact, it usually takes around six months to really get settled.

Anyway, in late January this year, I was still very much adjusting to the new flow. I have a heavy shift at the coffee shop of 6am to 3pm on weekdays. It's busy, and I'm very tired. My bosses are kind enough to let me get parcels delivered directly to the store, which is really helpful, as I'm only home one day a week. Generally, I walk to work as well. It's only about 10 minutes each way, but going home requires me to climb up a massive hill. On this particular day, I got three parcels delivered—all of them brand-new Super graphics cards.

Because I have so many parcels, out of kindness, a close colleague of mine, Lauren, offers me a lift home. I knew at this point that a) my dog has been home for five hours on her own, and b) the house is in a bit of a state. I've got far too many parcels, packaging, cardboard, and washing. It's all over the place. Still, it's three heavy boxes, Lauren is adamant that I accept, and wants to see the dog (she's the best kind of person: a dog person). So reluctantly I say yes, but pre-warn her that the house is a bit of a state and not to judge me.

Lauren gives me a lift home and comes in to see the dog, who gets overly excited because she loves people, and decides to accidentally urinate on Lauren's foot. Great. Real swell time for me. I apologize profusely, clean up, keep apologizing (still to this day), and Lauren goes on her way (we're still friends, don't worry).

So at this point, I am wracked with guilt and shame. My other half rings me up on her way home, I explain the situation, she calls me an idiot because I knew the house was a mess, and then promptly takes me to McDonald's to alleviate my suffering. At this point, I go out and buy a Eufy L60 Robot Vacuum with Self Emptying Station.

Aside from getting my life in order, and the work-life balance being a lot smoother, this thing has changed everything. I used to vacuum once a week on my day off—now, Hugh (my L60) does it daily at 5pm, and it is incredible. It doesn't always get everything, but the fact that it goes around once a day means it picks up pretty much everything dog hair-related, and just takes the stress away from it. Every day I get home, take an hour or two to relax, and at 5pm like clockwork, me and the dog sit on the couch and watch as Hugh does his rounds, vacuuming up my Labrador's double-layer coat from the floor.

It wasn't cheap, but chit is eaper than a lot of similar options. It's quiet, although you can ramp up the suction speed. It detects obstacles, scans the room, has LIDAR, and does a pretty good job on both wood flooring and on carpet. I always wanted a Roomba, but they're so expensive. Honestly, if you have a dog, and you've not got a robot vacuum, you definitely need one. I guarantee it will change your life. **–ZS**

$400, www.eufy.com

Reviewed...









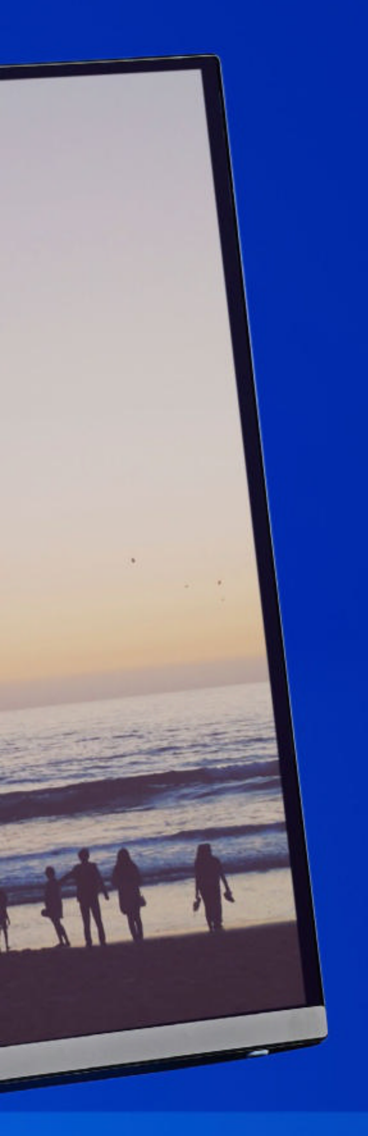




Like other 4K OLEDs, this Alienware is an elusive angstrom or three away from perfection.

Alienware 32 AW3225QF

Demanding but stunning 4K OLED gaming



ALL NEW TECHNOLOGIES come with a learning curve. With the cataclysmically desirable Alienware 32 AW3225QF, we're taking some lessons about OLED as a display solution for PC gaming. Yes, this is another of the brave new 4K monitors running a Samsung QD-OLED panel.

We've cast our eyes across several of these now, and the wow factor remains. But with familiarity comes a slightly more grounded sense of what these monitors offer gamers. However, let's kick off with the basic speeds and feeds. Again, we're talking 32 inches of 4K QD-OLED glory. Response is rated at 0.03 ms, peak HDR brightness at 1,000 nits, full screen brightness at 250 nits, and color coverage comes in at 99 percent coverage of the DCI-P3 gamut. The subpixel structure also remains the same. In other words, it's still not a conventional RGB stripe, but a triangular RGB arrangement.

That mattered in the past for sharpness and font rendering, because Windows addresses monitors under the assumption of the RGB stripe. But with the increased 140 DPI density of this new 32-inch 4K class of OLEDs, it's no longer an issue. Fonts look nice and crisp.

The other headline feature is the 240Hz refresh, of course. Obviously you'll need one heck of a GPU to feed all those pixels at 240Hz. Other highlights include DisplayPort 1.4 plus two HDMI 2.1 connections and a USB hub. What you don't get is USB upstream for video input or laptop charging. Nor is there an audio out for headphones or speakers, which is a slightly odd omission.

Rounding things out is Alienware's signature aesthetic, with the familiar white cladding on the rear of the chassis. I'm not a huge fan of the look, but it's well put together. But what about the image quality itself? No surprise, it's a stunner. The triple whammy of perfect per-pixel OLED lighting with 4K pixel density and a glossy panel coating is to die for.

In SDR mode, there's no brightness variability. You can move or resize windows as much as you want—the brightness stays at the same 250-nit level. That said, the Alienware 32 AW3225QF has even more pop in HDR, and that applies to SDR content, too.

As for HDR, the Alienware 32 AW3225QF gives very different results depending on which of the nine HDR modes you choose. Making matters worse, when switching between some, but not all, of the HDR modes, the display may resync with your PC.

Then there's the fact that the HDR 400 mode looks best for outdoor scenes, but crushes details for darker indoor and night-time game scenes, while HDR 1000 looks spectacular for the latter, but dull for brighter images.

If that wasn't enough, you also have to contend with OLED burn-in. Alienware covers the panel for three years, but you still have to put up with burn-in mitigation measure prompts popping up, and generally stress over whether you should toggle the 'Pixel Refresh' or 'Panel Refresh' protection algorithms. Life was a lot simpler with an SDR LCD monitor.

The upside, of course, are visuals that no LCD display can match, not even the latest and greatest IPS models with full-array local dimming. The contrast this Alienware delivers is awesome. Then there's the very fast pixel response. There's a clarity to movement on these OLED screens that no LCD panels can get close to, so this is undoubtedly a seminal gaming experience. Despite the slight complications, this is as good as OLED gaming gets. **–JEREMY LAIRD**

VERDICT 9

Alienware 32 AW3225QF

+ SCREEN QUEEN Stunning QD-OLED panel; 4K pixel density.

– DRAMA QUEEN Not exactly cheap; Complicated to use.

$1,199, www.dell.com

SPECIFICATIONS

Screen size	32-inch
Resolution	3,840 x 2,160
Brightness	250 nits full screen, 1,000 nits max HDR
Color coverage	99% DCI-P3
Response time	0.03ms
Refresh rate	240Hz
HDR	DisplayHDR 400 True Black, Dolby Vision
Features	Samsung QD-OLED 3rd Gen panel, Adaptive Sync, 1x DisplayPort 1.4, 2x HDMI 2.1



Lexar's NM790 not only looks the part, it's an absolute value king.

2TB Lexar NM790 PCIe 4.0 M.2 SSD

Flawless pricing gives this drive a competitive edge

THIS MIGHT be the best-value PCIe 4.0 SSD we've found to date. Usually, when we say something like that, there's a massive trade-off to be had at the same time. Like, "Oh wow, this GPU drives some seriously impressive frames and is super affordable, but by the way, it's louder than a jet engine". With the NM790, though, that's not the case—for a PCIe 4.0 SSD, it's seriously impressive. Not only are the performance metrics up there with some of the best PCIe 4.0 drives we've tested, but it trounces some of our favorite drives from a value perspective, both for gigabytes per $ and sequential read performance per $ as well.

Let's talk numbers and what you get—top-line specs. 2TB of total capacity on the PCIe 4.0 standard, with an M.2 2280 form factor. It's utilizing 232-layer YMTC TLC NAND flash memory. YMTC (Yangtze Memory Technologies) is a relatively new Chinese semiconductor company that's just been launched onto the scene with its own 232-layer TLC. Lexar's combining that with the Maxio MAP1602 controller, and impressively no DRAM or cache whatsoever. The drive is also entirely single-sided, even in its 4TB configuration, making it perfect for use in consoles or similar devices where the bulk of your cooling is situated on top.

The drive is available in capacities ranging from 512GB all the way up to 4TB respectively, and our variant comes with a 1500 TBW endurance rating and a five-year warranty. Advertised specs top out at 7,400 MB/s read 6,500 MB/s write, and IOPs at 1000K and 900K.

But stats only get you so far, and fortunately, we can report that the NM790 doesn't exactly disappoint when it comes to testing performance, either. CrystalDiskMark saw sequential reads and writes at 7,092/6,621 MB/s respectively, with random 4K topping out at 70 and 263 MB/s as well. That puts it on par, at least in terms of sequential performance, with the likes of our tried and true favorite, the Kingston Fury Renegade. However, it also pulls ahead when it comes to the random 4K performance as well.

Crucial's T500 is also an intriguing comparison, as similarly, it pulls away significantly on the sequential read front, and on random 4K performance as well. This is likely due to a lack of cache and DRAM, hindering the Lexar NM790, although that reduces power draw and sustained temperature peaks as a result, certainly over longer file transfers. In our testing, the NM790 topped out at around 75 C during our benchmarking process, which is well within healthy parameters.

However, it's when you start to dig into the pricing for this beautiful little thing that the coin drops, and that's for one reason: the value is insane. Okay, when we picked this up for our feature build, it was available for $147. At time of writing, it has fallen to $121. That's cheaper than the Kingston Fury Renegade ($187) and T500 ($139), in no small part thanks to YMTC's TLC NAND being somewhat cheaper.

It's that $121 that really swings the needle. That said, even at $147, it's still phenomenally good value. At that price, gigabyte per $ hits 13.61, close to the T500's 14.39 and higher than the Kingston's 11.56, and sequentials clock in at 48.25 versus the T500's 56.68 and the Kingston's 40.34 respectively. Drop the price to that $121 mark, though, and gigabyte per $ shoots up to 16.53 (surpassing the T500), and sequentials to 58.61 MB/s, making this by far the best-value SSD we've tested to date, as long as it holds its price lower than the T500.

The Lexar NM790m then, is the whole package. Performance? Check. Hardware? Check. Endurance? Check. Price? Near perfect. What's not to love? **–ZAK STOREY**

BENCHMARKS

	2TB Lexar NM790 PCIe 4.0 M.2 SSD	2TB Crucial T500 Pro PCIe 4.0 M.2 SSD	2TB Kingston Fury Renegade PCIe 4.0 M.2 SSD
AS SSD Sequential Read / Write (MB/s)	**5,955 / 5,152**	5,631 / 4,455	5,598 / 3,970
AS SSD Random 4K Read / Write (MB/s)	77.18 / 144.08	81.37 / 277.75	**85.21 / 281.32**
AS SSD Access Time (ms)	**0.016** / 0.045	0.018 / 0.017	0.062 / **0.016**
CrystalDiskMark Sequential QD32 Read / Write (MB/s)	7,092 / 6,621	**7,879** / 6,783	6,979 / **6,874**
CrystalDiskMark Random 4KQ1 Read / Write (MB/s)	70 / 263	**92** / 331	88 / **357**
Max Temp Under Load (C)	75	72	**55**
Gigabyte per $ (GB)	**16.53**	14.39	11.56
Sequential Read MB/s per $ (MB/s)	**58.61**	56.68	40.34

Best scores in bold. Our test bed consists of an Intel Core i9-14900K, 32GB of Corsair Dominator Titanium @ 7200, an Nvidia GeForce RTX 4080, Corsair H150i AIO, and an Asus Z790 Dark Hero. Max Temp recorded via HWMonitor during benchmarking process. Prices correct at time of writing (Lexar NM790 pricing metrics listed at $121).

VERDICT 9 KICK ASS!

2TB Lexar NM790 PCIe 4.0 M.2 SSD

+ NATURALLY MAGNIFICENT Flawless price point if it holds; Strong PCIe 4.0 performance; Solid endurance rating; Decent temperatures and power draw.

– NEVERMIND Unproven TLC NAND; Lower 4K performance.

$121 - $147, www.lexar.com

SPECIFICATIONS

Variants	Stock only
Form Factor	M.2 2280
Interface / Protocol	PCIe 4.0 / NVMe
Flash Memory	232-Layer TLC NAND Flash
Sequential Read	7,400 MB/s
Sequential Write	6,500 MB/s
Random Read	1000K IOPS
Random Write	900K IOPS
Endurance (TBW)	1500
Warranty	5-year limited warranty



The thin screen means the inputs are a long way from the edge. The screen is blacker than its bezel when switched off.



Acer Predator X27U

The latest in a long line of gaming monitors embraces the OLED

WE LIKE OLED monitors, their thinness and brightness appearing contradictory yet strangely alluring. Add the 240Hz refresh rate of this Acer Predator, and you have a winning combination.

The resolution of 1440p looks like a wise choice, even though it's a step down from the old Quantum Dot Predator X27's 2160p. By showing restraint and dialing it back a bit, Acer is able to increase the chances that today's GPUs will be able to supply the high frame rates a screen like this deserves. It'll display them without tearing, too, thanks to Freesync Premium and VRR support, though it drops the G-Sync certification of its predecessor.

You also get plenty of ways to feed it those frames. At the back of the X27U, there's an array of ports that includes a useful USB hub, alongside the usual HDMI and DisplayPort options. They're not particularly easy to get to, as while there's a thicker part of the monitor inset from the extremely thin edge, it's a long way up, and the ports are quite close together. It's best to plug some cables in and leave them there, especially as you've got a USB-C port for compatible laptops (it provides 90W of power to charge them, making a tidy single-cable solution), which can switch USB data—perhaps a flash drive, wireless keyboard receiver, or webcam—with the Type-B/A hub. Hook your desktop PC up to the DisplayPort, use the HDMIs for a streaming stick and your Nintendo Switch dock, and you've got a complete media hub.

Audio is taken care of by 5W speakers, which are surprisingly clear considering how slender the edge of the monitor is. You'll still be better off using headphones or external speakers, but they're good enough for a video call. A handy accessory screw socket at the top of the monitor stand allows the attachment of cameras or ring lights, so you can look your best.

That stand allows for a decent degree of adjustment, though there's a six-inch VESA mount at the back if you want to connect it to an arm. There's almost six inches of vertical adjustment, as well as the ability to swivel the screen into a portrait orientation. The foot features widely splayed supports, which take up a chunk of desk space, but the rear leg is small enough that you're not forced to place it too far from the edge.

The screen is the main draw. Switched off, it appears as a pure black portal to another dimension where the stars never ignited, but feed it the requisite signal, and you're treated to some excellent color saturation, with up to 400 nits of brightness if you've got HDR switched on. The blacks are deep, too, offering the kind of contrast LCD screens can't manage. It can display 93 percent of the P3 color gamut (in our tests—Acer's claim is for 99 percent), which is very respectable.

All 3.68 million of those OLED cells combine to produce a picture that's sharp and responsive, the benefits of the technology making themselves clear behind the anti-glare matte coating. The only real problem is its price. At close to $1,000, you need to really want it to buy it, and the eye is easily drawn by LED-backlit IPS screens that offer 90 percent of the OLED's performance for half the price. Acer's screen is the complete package, offering size, resolution, and speed, but it sure does cost a lot. **–IAN EVENDEN**

VERDICT 9

Acer Predator X27U

+ PREDATOR Excellent OLED display; USB hub; Plenty of inputs.

− PREY Very expensive; 'Only' 1440p; External power brick.

$999, www.acer.com

SPECIFICATIONS

Screen size	27in
Panel	OLED
Resolution	2560 x 1440
Brightness	400 nits (DisplayHDR 400)
Refresh rate	240Hz
Audio	2x 5W speakers
Connectivity	2x HDMI 2.0, 1x DisplayPort 1.4, USB Type-C (90W PD), 1x USB 3 Type-B, 2x USB 3 Type-A
Dimensions	22.4 x 23.8 x 2.2in (with stand)
Weight	13.45 lb (with stand)

HP Spectre Foldable

All the gear, no idea

FOLDABLE SCREENS are everywhere now. We first saw them pop up in the mobile world, then they made their way to monitors with the likes of Corsair's Xeneon Flex, and now we have them in laptops, too (if this can even be called a laptop). You see, the HP Spectre Foldable is technically a laptop, an all-in-one, and a tablet. Its downfall is that it's a $5,000 tablet with sub-$1,000 performance.

Yeah, that's kind of the problem with the HP Spectre Foldable. On the surface, it is an incredibly versatile device. You've got a crisp, beautiful OLED panel with some solid pixel density, that is entirely foldable, with a detachable, magnetic wireless keyboard and mouse combo. That allows you to do a few things: first, you can just use it as a full-on display plus a wireless media keyboard. There's a kickstand embedded into the back of the product—pop that out, and you get a full-size 17-inch 2560x1920 16:10 display. Alternatively, flatten it out entirely, turn the keyboard off, and you've got a chunky 17-inch tablet instead.

The real party trick comes when you bend the screen in half, however. Fold that into a laptop shape, and you can attach the keyboard in a number of different ways: either on the bottom half of the screen entirely to turn it into a remarkably compact laptop, or pull that keyboard down a touch, and you can give yourself a bottom half display as well. HP has included a bit of software wizardry here, too, that will shift the resolution and Windows display to compensate, accurately detecting the keyboard on top, which also simultaneously charges wirelessly when in position.

Overall, the design is solid. The materials are great, and that display is crisp and vibrant— exactly what you'd expect from an OLED. It's a little disappointing that it's only 60Hz, but that's not the end of the world. There are two USB Type-C connectors on the Foldable, both supporting Thunderbolt and charging. HP also includes a USB Hub, so you can connect additional devices and displays to it if you need to. That said, the ports are a bit oddly placed. If you do decide to use it as a laptop, there's only one 'portrait' orientation you can use the screen in (the device does automatically rotate the screen, depending on how you're holding it), and in laptop mode, you get one USB-C port at the top left of the primary display, and one on the right-hand side of the screen, making it a bit awkward to plug things into.

Those are minor foibles that really don't detract from the overall device. There's a problem, however, and it's the internal spec. As standard, there's only one SKU for the foldable. You get 16GB of LPDDR5 RAM soldered onto the unit, an Intel Core i7-1250U CPU (theoretically capable of 4.7 GHz with 12 threads), and a 1TB PCIe 4.0 SSD, and, well, that's it. On the one hand, this is great, as it does extend the battery life fairly comfortably (which changes, depending on how much of the screen you're using)—on the other, performance is poor; very poor. We won't go too deep into the numbers here, but compared to a $1,200 entry-level laptop, outside of CrystalDiskMark, it consistently performed worse across pretty much every benchmark we ran it on. For our gaming benchmarks, it failed every single one, often loading the game menu, but crashing when attempting to run it, even on the lowest settings.

Here's the thing: it's not designed for that, and we kind of forgive it. If light desktop work is your thing, and internet browsing and some Netflix streaming is your aim, then it's perfect. The problem, however, is that Asus actually has an almost identical model to this (spec, foldable panel, internals—the lot) for $2,000 less (yes, you did read that right) called the Asus Zenbook 17 Fold OLED. What we're left with is a very impressive tech demo that costs far more than it should, and performs worse than most $1,000 laptops. It may be cool, but that's not really good enough. **–ZAK STOREY**

VERDICT 6

HP Spectre Foldable

+ FOLDING@HOME Intriguing tech demo; Beautiful screen; Solid design.

– FOLDING LIKE A LEAF Price is way too high; Performance is massively underwhelming; $2,000 cheaper options.

$5,000, www.hp.com

BENCHMARKS

	HP Spectre Foldable	Huawei MateBook D 16 2024 (EU Only)
Crossmark Aggregate (Index)	1,405	**1,938**
GeekBench 6.2.1 Single-Core / Multi-Core (Index)	2,210 / 6,635	**2,605 / 12,568**
Blender (Index)	26.81 / 17.14 / 11.69	**70.22 / 40.94 / 28.38**
CrystalDiskMark 8 Read/Write (MB/s)	**6,739 / 4,524**	4,905 / 3,952
3D Mark Wildlife Extreme	DNC	**13,731**
Total War: Warhammer 3 Low @ Native Resolution (avg fps)	DNC	**33.9**
Borderlands 3 Ultra @ Native Resolution (avg fps)	DNC	**10.27**

All benchmarks performed with a clean install of Windows 11, with the latest updates, chipset and drivers installed. Best scores in bold. Games tested at device's native resolution. Borderlands 3 tested at Ultra, Total War: Warhammer 3 tested at Low.

SPECIFICATIONS

CPU	Intel Core i7-1250U
GPU	Intel Iris Xe Graphics
RAM	16GB LPDDR5-5200
Storage	1TB PCIe 4.0 M.2 SSD
Screen	17-in 2560x1920 OLED
Connectivity	2x USB Type-C Thunderbolt, WiFi 6E, Bluetooth 5.3
Dimensions	10.9 x 14.80 x 0.33 in
Weight	3.57 lbs



If only HP could fold that price in half. They might be on to something.

Acer Predator Helios Neo 16

With the latest tech comes the same old problems

GAMING LAPTOPS come and go, but some things stay the same. The combination of a hot CPU and capable GPU, along with plenty of RAM and some fast storage, always adds up to a potent gaming experience that can't last long away from a wall socket, and so it is with Acer's latest, the Predator Helios Neo 16.

It's packing a 14th-gen Raptor Lake Refresh CPU, rather than one of the Meteor Lake Core Ultra chips, which means 20 cores (eight of them P cores), a maximum boost frequency of 5.5GHz, and a TDP of as much as 157W. Add to that the 140W that the RTX 4070 GPU is capable of slurping, and this doesn't go well on the battery, which in our tests can scrape just three hours and 19 minutes, even in our relatively gentle test, which keeps the screen on and subjects it to a series of office tasks.

Still, once you get it plugged in and actually start gaming on it, the Helios Neo is pretty good to use. It's fairly heavy, which grounds it on your desktop and, as a 16-inch laptop should, it takes over the space you put it in more than a smaller model would. The weight means it's sub-optimal when you put it on your lap, but there's another reason that it belongs on a hard surface: it gets hot. The fans spin up just from the Windows login page, and it gets warm even when sitting idle. Start pushing up the processors, and the cooling system is called upon to dissipate a lot of heat, leading to plenty of fan noise.

You'll no doubt have a headset or pair of Bluetooth headphones attached, however, or even use the built-in speakers which, like a lot of their kind, are fine, but not great. The keyboard is RGB backlit and feels somewhat cramped, as a numpad has been squeezed in alongside it, but the keys have plenty of travel. It's notable as one of the first devices we've seen to sport Microsoft's new Copilot button on the keyboard between the spacebar and the arrow keys, which is alongside the Predator button at the top of the numpad. This didn't seem to do anything in our tests, but we suspect this may be meant to launch the PredatorSense software that controls performance profiles, RGB lighting, and other personal settings.

The screen is an IPS with a 240Hz refresh rate and 1600p 16:10 resolution, which is going to attract fans of esports and online shooters, where quick reactions are paramount. To make a connection, you have the choice of Wi-Fi 6E and a 2.5Gbps Ethernet port, although you'll need compatible equipment all the way along the network chain to make the most of this. It also has an array of USB ports, including two Thunderbolt 4s with lightning bolt logos next to them. We couldn't get it to charge through them, although Acer says it should be possible, and the power brick that comes in the box is very large—even the flex that attaches to the laptop's charging port seems thicker than others. You'll need that power adapter, as the battery life isn't great. Start gaming, and it will only get worse: we saw it run out in just over an hour after one session.

The Acer Predator Helios Neo is a well-specced gaming laptop that's been released into a competitive marketplace in which there are a lot of other options at the same price. Its performance is good, but it doesn't always look like a bargain.
–IAN EVENDEN

VERDICT 8

Acer Predator Helios Neo 16

+ HELIOS Good processor choices; Nice screen; Keyboard has great feel.

– HEINOUS Poor battery life; Heavy; Gets hot underneath.

$1,699, www.acer.com

SPECIFICATIONS

CPU	Intel Core i7-14700HX (20 cores)
GPU	Nvidia GeForce RTX 4070
RAM	32GB
Storage	1TB SSD
Screen	16in IPS, 2560x1600 pixels (16:10), 240Hz
Connectivity	Wi-Fi 6E, 2.5G Ethernet, Bluetooth 5.3, 1x USB 3.2 Gen 1 Type-A, 2x USB 3.2 Gen 2 Type-A, 2x USB 3.2 Gen 2 Type-C, HDMI, Micro SD, 3.5mm (0.13in) headset
Dimensions	1.1 x 14.2 x 11in
Weight	6.1lbs





The black plastic casing picks up fingerprints easily, so you might need to carry a cloth.

Benq X500i 4K Short Throw Projector

4K gaming projection just got cheaper... sort of

PROJECTORS ARE STILL difficult to justify on so many levels. The biggest reason is what kind of screen tech we have available to us. No matter how you spin it, a 4K gaming projector's main advantage is screen size. Everything else, from color accuracy and latency to image clarity, is superseded by the monitor tech we have, typically at far lower prices, too.

If you're looking at a projection unit like this to replace your desktop monitor, we'd say that it's not worth considering. If you want a beefy 42-inch monitor, then you can grab something like Asus's ROG Swift OLED PG42UQ, complete with 137 Hz refresh rate, 0.1ms response time, and 4K 41.5-inch panel for less than $950. If you want something ultrawide, then Alienware's AW3423DW, complete with 34-inch form factor, 3440x1440 resolution, 0.1 ms response, and 175 Hz refresh rate, comes in at just shy of $1,100, and you can find even cheaper solutions from Samsung and other manufacturers. No matter how you spin it, the humble monitor is better if you want the absolute best experience on your PC on your own.

But that's the twist—a projector isn't really designed for that kind of use. It's not meant to be a desktop replacement, nor is it best enjoyed alone. No, this is a product that really makes itself at home in a dedicated gaming den, man cave, home theater, or family room. When it comes to getting a top-tier 4K gaming experience, very few projectors come close to what the X500i can achieve.

We've been using the X500i for a few weeks now, and out of all of Benq's projector product stack, we're not sure why you'd go with anything else. Admittedly, out of the three brand new projectors from the company, there's not a lot to choose from—just the X3100i, with its vast $2,400 price tag, the X500i, or the portable X300G 4K gaming projector at $1,800. The X500i sits in comfortably at $1,700, but in our opinion, is far superior to its X3100i counterpart.

Why? It comes down to a mixture of features, price, and form factor. Out of the box, the X500i's image quality is top-tier. One of our tests involve shining our projectors against a dark gray wall to see how they handle the color difference compared to a white screen, and the X500i dominated that test. Colors are crisp, vibrant, and accurate. On a relatively short 18-foot throw, the X500i produced a fantastically clear image, and latency was almost non-existent. Benq has also included some serious connectivity (we'll let the spec box do the talking), and Google TV is built in for a super-smooth setup. The chef's kiss, however, is the configuration menu. There's a lot on offer, including everything from high-altitude mode to keystone adjustments, game modes, and HDR tweaking. It also packs some impressive audio, certainly in contrast to some of the competition.

The best thing about the X500i, though, is the form factor. It's sleek, slender, and more traditionally rectangle-shaped, rather than the cuboid that the X3100i and X500G offer. That allows you to mount it to the ceiling without worrying about walking into it at night. Build quality is solid, and the remote is slick.

It's not flawless, however. Fan noise is an issue, particularly if you're on Netflix or YouTube, and the Google TV implementation feels flimsy (it's a dongle that you insert into the back, hidden behind a plastic cover, with a bendy Micro-USB cable, and HDMI connector).

Still, the X500i easily contends with the likes of the X3100i for image quality and then some, and that's what makes this thing so impressive. If you're after a 4K gaming projector to dabble in some casual gaming with your friends and family on a long weekend, then the X500i more than fits the bill. **–ZAK STOREY**

VERDICT 9

Benq X500i 4K Short Throw Projector

+ XCEPTIONAL Solid image clarity and color accuracy; Easy setup; Decent form factor; Good pricing.

– XCREMENT Noisy fans; Janky Google TV implementation; Bigger screens may need the X3100i.

$1,700, www.benq.com

SPECIFICATIONS

Resolutions	640x480 up to 3840x2160. 4K@60 Hz, 2K@120Hz, 1080p@240Hz. 60Hz limited to 16.7 ms, 120Hz 8.3ms, 240Hz 4.2ms.
Display Colors	1.07 billion
Contrast Ratio	600,000:1
Brightness	2,200 Lumens
Light Source Life	20,000 - 30,000 hrs
Zoom Ratio	1.2x
Throw Ratio	0.69 - 0.83
Projection Offset	102.5%
Connectivity	2x HDMI 2.0b, 1x USB Type A, 1x USB Type C (DisplayPort), 1x RS232 In, 1x TOSLink Optical Audio Out, 3.5mm Analog Audio
Weight	7.9 lb
Dimensions	4.6 x 14.4 x 9.6 inches



The X500i really makes us question why the X3100i exists.


4K HDR
X SERIES PROJECTOR
BenQ
PROJECTOR MENU
BenQ

Phanteks XT Pro

$50 goes a long way these days



THERE'S NO DOUBT that we here at *Maximum PC* spend a lot of time looking at expensive products. Whether that's a $400 chassis with screens in it, or $2,000 graphics cards, a lot of them really have no right to be as expensive as they are. Often, budget options are by far the more interesting products. Discovering the best-value chassis, CPU, or SSD is far more challenging than seeing that fps number climb ever higher (this journalist's discerning eyes aren't as sharp as they used to be). Still, Phanteks' XT Pro is one such product.

Straight out of the gate, this thing comes in at $50. That is incredibly low for a case. It's been a very long time since we've seen a chassis at that price that wasn't covered in fingerprint-inducing plastics, "gamer" design choices, or bare steel panels. The XT Pro is a nice change of pace in that regard, and really does go to show how far case manufacturers have come in terms of design and manufacturing in the last decade or so.

On the surface, the XT Pro is a sleek, smooth, crisp black tower, with a tempered glass side panel and plenty of support for your componentry inside. It can house up to an 11-inch E-ATX motherboard, and has some serious cooling support baked in as well.

It's that cooling potential that really tips the scales in its favor. By default, you can fit it out with a 4.7-inch rad in the rear, a 14-inch in the roof, and a 9.5-inch up front. In fact, you can do that and still have a ton of clearance both top and bottom. It gets even more impressive when you look at the number of fans you can stick in this thing, as there's support for up to 10 4.7-inch fans total, including three on top of the PSU shroud, to draw cool(ish) air up from that compartment directly into your GPU and above componentry. Couple that with a decent-sized 5.5-inch up front, drawing cool air into that compartment, and it gives you an incredibly potent cooling solution.

Alternatively, you could run three 4.7-inches on that PSU shroud, an AIO with three 4.7-inches in the roof, one 5.5-inch in the rear as an exhaust, and three 5.5-inches up front as an intake to really maximize on that potential. It's just glorious, and a real nice touch, particularly when most cases at this price point really don't support anywhere near as much cooling.

The XT Pro is somewhat limited on what you get with it as standard, however—there is only one fan included, although you can pay $20 extra for the XT Pro Ultra (available in either black or white), and that comes with a total of four M25-140mm D-RGB fans as standard too. This is an impressive saving (we actually included the triple 4.7-inch kit in our feature build this issue on page 16).

Otherwise, it's not entirely dissimilar to something like the Corsair 4000D Airflow. The internal layout is very similar. There's a huge amount of compatibility here for GPUs, CPU towers, and more, but all at a super-low price.

You can tell where corners are cut—some of the materials are on the lower-quality end—but it's not distracting by any means. If Phanteks had pitched this case in its standard config as $70, we'd have thought this was a good deal. At $50, it's outstanding. –ZAK STOREY

VERDICT 9

Phanteks XT Pro

+ XENEPHON OF GREECE Strong pricing; Easy to build in; Insane cooling potential; Excellent compatibility.

− XYLOPHONE OF KINDERGARTEN Materials do feel cheap; Could use one extra fan in $50 config.

$50, www.phanteks.com

SPECIFICATIONS

Motherboard Support	ITX, Micro-ATX, ATX, E-ATX (12 x 11 inches)
2.5-inch / 3.5-inch Support	2 x 2.5 inch, 1 x 3.5 inch/2 x 3.5 inch
Max Radiator Support	4.7 inch rear, 14 inch roof, 9.5 inch front
Fan Support	3 x 4.7 inch/2 x 5.5 inch roof, 3 x 4.7/5.5 inch front, 3 x 4.7 inch PSU cover, 1 x 4.7/5.5 inch rear
Dimensions	17.7 x 19.7 x 9.1 inches
Graphics Card Clearance	16.33 inches
CPU Tower Clearance	7.24 inches
Warranty	5 years limited



Cherry Xtrfy K5V2

New switches, who dis?

CHERRY'S SWITCHES are dependable, unwavering, and the standard by which many of us judge all other switches. So what happens when Cherry changes them? You get the MX2A Red switches inside the Cherry-made Xtrfy K5V2—a new and improved version of the Cherry MX Reds we've come to know and love.

The MX2A Reds are an improvement in a number of ways. First and foremost, they're factory lubed. If you're a regular reader of our keyboard coverage, you'll know that lube makes for smoother switches with a satisfying clack. That's certainly true of the MX2A Reds, too. Each key glides effortlessly with each strike from my fingers.

The MX2A switches come with 'pin point ring lubrication' applied to the new 'socket dome' in the bottom housing. If that sounds like jargon, it sort of is, but in effect means each switch leaves the factory floor with a big dollop of grease in it, and which should stick around for the lifetime of the switch.

Other upgrades with the MX2A switches factor into the more consistent key press, including a new barrel spring, housing socket dome, guidance ribs, and stem geometry. That last one is important, as the MX2A are significantly less wobbly than older MX Reds.

All of those changes make for a much smoother key press than with previous Cherry MX Red switches. Overall it's a much better switch than the original MX Reds. That's good news for gamers, as we're likely to see a lot of them end up in gaming keyboards from multiple brands.

But how does the typing experience on the Cherry Xtrfy K5V2 compare to our favorite keyboard of the moment, the ROG Strix Scope II 96 Wireless? Put simply, we prefer the Scope II 96 for typing. The lack of wobble in the PBT keycaps through the ROG NX Snow switches is as impressive now as the day we first tried it.

Onward to the keyboard itself. This is a compact slab with a 65 percent layout. That means it's only 12.8 x 4.4 inches, and doesn't come with a numpad or the usual cluster above the arrow keys. It does retain arrow keys, however, along with Page Down, Page Up, and Delete keys. The rest of the missing keys can be accessed via the many, many shortcuts on this keyboard.

End, Home, and the F1-F12 keys are accessed with a press of the Function key. To make up for the lack of physical media keys, there are some shortcuts thrown in along the top alphabet row. What I find a little overwhelming are the many more shortcut keys for functions with unclear intentions. There's one key of mysterious machination with a fingerprint blazoned on it, another says K-LED. BG Color, K-Slow, K-Fast, K-Mask, E-speed+, the list goes on. All those we've mentioned control the RGB lighting on the board, and the reason why there are so many pre-programmed keys to do so is due to the lack of dedicated Cherry software to control this keyboard. That may appeal to some, though if you want simplicity, we'd look elsewhere.

The keycaps are made from ABS plastic, which feels like a bit of a miss for the money, but they're easily replaceable thanks to MX cross stems. The switches themselves are also hot-swappable, and the USB Type-C to Type-A cable removable. All of this should see this keyboard last a long time—at least until those switches wear out around the 100 millionth click mark.

You'll have to part with $140 to get yourself in on the Xtrfy action. It's a neatly packaged gaming keyboard with plenty of functionality for its lack of software, which for some may be all they need to hear, but nevertheless feels like a lot of money for fewer keys than most. There are nicer-feeling—and cheaper—compact keyboards. Nothing about the Xtrfy makes it sing for us. –JACOB RIDLEY

VERDICT 7

Cherry Xtrfy K5V2

XTRFY Steady switch; Good typing experience; Great for gaming; Software free; Hot-swappable.

XTNCT RGB lighting controls are finicky; Cheaper wired compact boards available.

$140, www.cherryamericas.com

SPECIFICATIONS

Size	65%
Connectivity	USB Type-C to Type-A
Keycaps	ABS
Switches	Cherry MX2A Red
Hot-swappable	Yes
Media controls	Shortcuts via Function key
Lighting	RGB lighting modes + onboard control
Software	None

HyperX Cloud III Wireless

These are not the headphones you're looking for...



LET'S BE GENEROUS and start with the positives. The Cloud III Wireless offers a sturdy build that didn't creak, bend, or break during two weeks of regular usage. The headset's earcups are held in place by a robust metal frame bathed in red, and the surrounds are all plastic. The ear and head cushioning is an initially comfy and uniform leatherette.

A volume wheel with a smooth, tactile action sits on the right earcup, with a microphone mute button, power button, and USB Type-C charging port on the left. The removable microphone extends out from the left earcup, connected via a slotted 3.5mm jack. This particular microphone comes with a small red light on the tip of the boom arm to indicate when it's muted—a handy visual cue and a good way to avoid talking to yourself.

It captures a tone favoring the upper ranges and with a subdued bass response. It's not a particularly natural-sounding microphone, but it is extremely clear. For gaming over Discord or in-game voice chat, boosting the higher frequencies is not a bad thing—the Cloud III's mic cuts through game audio like a knife through butter. However, if you want a headset that's better suited to streaming or recording your voice, you'll want to look elsewhere.

The 120-hour battery life brandished by the Cloud III Wireless is good compared to the wider market, and in a few weeks of testing it barely required charging at all. The dedicated wireless dongle, meanwhile, will work across PC, PlayStation, and Nintendo Switch thanks to an adapter in the box to change it from a native Type-C connection into a Type-A.

If that sounds useful, the dongle is also where the worm begins to turn. It seems to suffer interference issues with other wireless peripherals, including mice, causing repeated rogue disconnections and lost or distorted audio. That was solved by relocating the dongle into a port further from other wireless dongles, but it remains a concern.

Then there are the ergonomics. We weighed the Cloud III Wireless at 0.75 pounds, but four hours of usage left us desperate to get the things off. The same can't be said about, say, the AceZone A-Spire, over a similar period of usage. They're much more comfortable.

This leaves us with the final and most important factor: sound quality. The bass feels more pronounced on this headset than some more neutral headsets, yet lacks precision and definition. It's really trying to highlight the lower frequencies, yet the drivers just aren't capable of it. As a result, when the bass is kicking, it detracts from the rest of the mids and highs. Without any bass thumping, the high-end is better, and for a closed-back headset, it doesn't sound pointy or harsh. But the high-end response, too, is nothing to write home about.

The Cloud III is certainly better suited to gaming than music. It's reasonably easy to hone in on individual cues in-game, and while the soundstage isn't terribly impressive, this headset provides a decent enough gaming experience. But if you want to mix in some music listening, there are definitely headsets that do a better job of that broad remit.

All told, the Cloud III Wireless highlights an uncomfortable truth with wireless gaming headsets: you can pick up a fantastic-sounding pair of wired headphones for less than $100, but it costs a lot more for similar cable-free headphones. I've not been blown away by any wireless headset beneath the $150 mark. In that sense, and compared to similarly priced competition, such as the Corsair HS80 Max, the HyperX Cloud III Wireless is decent enough. Yet, it doesn't feel anything close to a legend in the making, like its more expensive sibling, the HyperX Cloud Alpha Wireless.
–JACOB RIDLEY



The HyperX Cloud III Wireless

+ IN THE CAN Good battery life; Decent build; Okay for gaming.

– CAN IT Connection issues; Tinny microphone; Muddy sound.

$150, www.hyperx.com

SPECIFICATIONS

Connection	2.4 GHz wireless (via USB Type-C dongle with Type-A adapter)
Type	Closed back
Frequency response	10 Hz – 21 kHz
Drivers	Dynamic, 53mm with neodymium magnets
Connector	USB Type-C
Microphone	Electret condenser microphone
Weight	0.75lbs (with mic)



Sleek, indomitable mothership jetting off into the unknown? It must be *Homeworld*.

REAL-TIME STRATEGY GAME

Homeworld 3

The Hiigaran fleet returns for a third outing

THE SIGHT OF THE SLEEK, indomitable mothership preparing to jet off into the unknown, accompanied by radio chatter and a moody score, feels like a homecoming. For newbies, it's a striking scene. For veterans, it calls to mind the original mothership getting ready to leave Kharak and the beginning of one of the best strategy games ever created. Welcome to *Homeworld 3*. It's enough to make you tingle.

Homeworld 3 wants to remind you of its legacy, a lot. After the events of *Homeworld 2*, Karan S'jet, the mothership's navigator, was sent on a mission to deal with a looming crisis, but never returned. 20 years later, her protege, Imogen S'jet, is following in her footsteps, with a new mothership and a new fleet that must strike out on their own, once again without support.

But where the original *Homeworld* often took a minimalist approach, *Homeworld 3* is comparatively busier, with maps full of debris and terrain, and a story that constantly breaks from the fun stuff to boring conversations in hideous cutscenes that look ripped from a bad '90s sci-fi game. The plot is mostly forgettable nonsense, so thank goodness the missions are largely brilliant.

Each puts the fleet in a new kind of peril. You'll be hiding from enemies in nebulae, commandeering gargantuan, monolithic space complexes, setting up elaborate blockades, using turrets and mines to create corridors of death, or sabotaging factories in kamikaze strikes.

The original *Homeworld* felt revolutionary thanks to its truly 3D battles, but *Homeworld 3* makes you appreciate the cosmic conflicts so much more thanks to space terrain. Every single mission is laden with screen-filling structures and asteroids, creating defensible positions, chokepoints, and ambush spots. How you approach a fight matters much more because while you have this complete freedom of movement, you also have maps that give you both advantages and limitations.

The complexity of the terrain-dense maps makes it harder to control your fleet, but it's easy enough to hop around, focusing on specific ships and groups. The attack move order means you can keep up the aggression, and being able to select groups of enemies to attack gives you room to deal with the big picture.

Still, some maps simply set in deep space would have been welcome. Full 3D movement already gives you plenty to deal with, and its predecessors' purity of space combat is missing. Sometimes, it feels like *Homeworld 3* is trying too hard.

There's also a new mode: War Games. It's an RTS take on roguelikes, where each run gives you only a specific ship loadout which can be buffed by artifacts you earn along the way. Every mission sees you bombarded by enemy incursions, which only grow in intensity. It punishes you for taking your time. The AI isn't any more reactive than the campaign's, but it's certainly more unrelenting.

Despite ostensibly allowing you to play solo, it just doesn't make sense without a co-op buddy. But even with a co-pilot in tow, the appeal is limited. You get fewer options, less time and more threats. None of this really plays to *Homeworld 3*'s strengths. It's good that developer BBI has tried something new, it shouldn't be entirely beholden to the past, but this ain't it, unfortunately.

Homeworld was such a formative title for gamers of a certain generation that it's hard to imagine anything knocking it



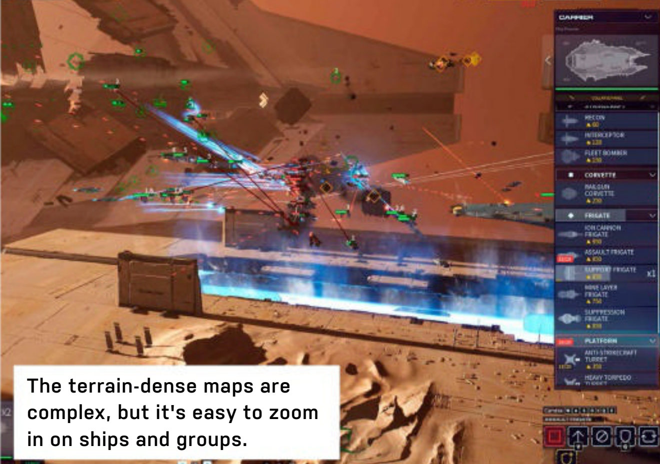
New play mode War Games is a spacefaring take on roguelikes.



Clunky cutscenes and a forgettable plot are offset by thrilling missions.



While playing solo is possible, we definitely recommend buddying up with someone.



The terrain-dense maps are complex, but it's easy to zoom in on ships and groups.

off its pedestal, but *Homeworld 3* does make it wobble—a bit. Watching dogfights in the canyons of a frozen moon or a formation of bombers boosting up the wall of an industrial complex, while praying some of them survive the turret fire, is undeniably thrilling stuff. But then you sit through another terrible cutscene, babysit your capital ships or do another run of War Games, the wobbling passes. This isn't quite the *Homeworld 3* we dreamed of, then. But there are times where it gets pretty close. –FRASER BROWN

VERDICT **8**

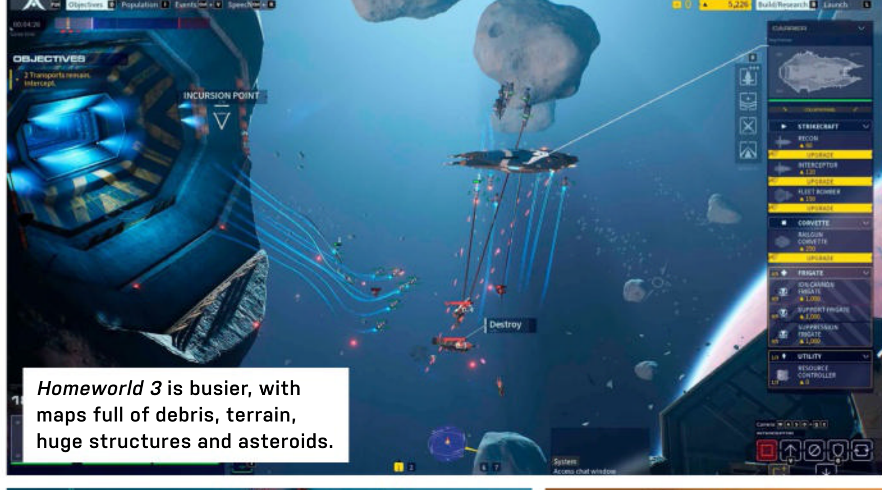
Homeworld 3

BRAVE NEW WORLDS Intoxicating nostalgia hit; Brilliant missions; Intriguing space terrain.

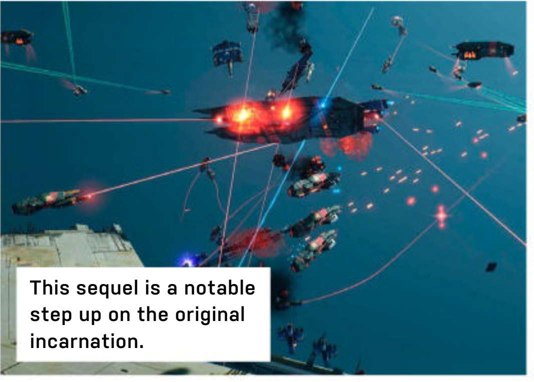
HIGHLY ILLOGICAL Terrible cut scenes; A bit too complicated; Unsatisfying new play modes.

RECOMMENDED SPECS CPU, Intel i5-9600K or AMD Ryzen 5 3600X. GPU, Nvidia GTX 1080 TI, AMD RX5700, or Intel ARC A580. RAM, 16GB. 40GB storage.

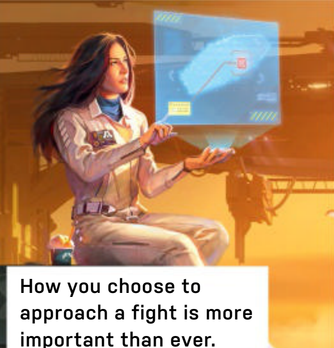
$59.99, https://www.homeworlduniverse.com/games/homeworld3, Rated 10+



Homeworld 3 is busier, with maps full of debris, terrain, huge structures and asteroids.



This sequel is a notable step up on the original incarnation.



How you choose to approach a fight is more important than ever.

Arc vs Chrome

A new challenger enters the battle of the browsers

THINGS HAVE BEEN relatively quiet in the world of web browsers for a while, if you overlook Microsoft's constant pressure on Windows users to switch to Edge. The MS browser has greatly improved since the switch to Google's rendering engine, Blink, itself a fork of Apple's older Webkit engine used in Safari. Microsoft also has Trident (Internet Explorer) and EdgeHTML (older versions of Edge), while Firefox runs on Gecko. There are others, too.

These engines affect the way websites, which exist as lines of code and image files on a server somewhere, are displayed on your computer. The differences between them mean they don't always render web content identically, especially in these days of embedded content, multiple coding languages, and plugins that mean a browser may be pulling information from many different sources to create the site you see.

What this means is that despite there being lots of different browsers, many of them are running on the same engine, and may not be as different under the hood as you expect. While this is good for consistency, and makes it easier to create standards-compliant web pages that will load well in any browser (cross-browser testing is an artform in itself), it does mean that there has been a distinct lack of innovation in the browser market, with things like chatbots being the biggest step forward since online accounts and syncing of bookmarks across computers.

There's a new browser on the block, though: Arc, and it attempts to shake up the web despite using the same Blink rendering engine as many of the other big players. What's different about it, though, is the way it changes the interface of the browser, which has remained largely the same since Windows 95.

ARC

Arc comes from The Browser Company, a startup founded by former White House director of product Josh Miller and software developer Hursh Agrawal. It differs from other browsers, which usually have a similar layout with an address bar at the top of the screen, by moving things to a sidebar on the left. This makes a lot of sense on our 16:9 or 16:10 screens, which have more space in the horizontal plane.

It's easy to install—just download the installer from arc.net, run it, and let it do its thing. Once the app is installed and you open it up, you'll be prompted to create an account, which means putting in an email address and creating a password. That sadly means signing up to marketing communications, but they're easy to unsubscribe from.

Arc's use of the Blink engine also means that all your Chrome plugins are compatible, and if you choose to transfer your bookmarks into the new browser, they'll come along, too. Once up and running, Arc added large buttons in its sidebar for Gmail and Google Calendar, bundled all our imported Chrome bookmarks into a folder, and provided a folder of tutorials for the browser itself. Under the bookmarks sit your tabs, each of which runs in a separate instance of the browser, meaning Windows' Task Manager shows a lot of running processes for the app—we spotted 16 with two tabs open, using about 650MB of RAM.

If, like us, you've been using browsers in largely the same way since the days when modems wailed and screeched to connect us to the web, doing things another way can come as a shock. Arc looks different to Chrome, Edge, and Firefox, but it brings with it some good ideas that are surely destined to be absorbed by its rivals.

One of the first that strikes us is the way you can snap tabs side by side in a

similar way to app snapping in Windows 11. If you want to change one of those tabs by typing a web address rather than following a link, you click on the title bar, and a pop-up appears into which you type, which is also how new tabs are dealt with. It can feel a bit clunky, but makes sense if your browsing is more mouse-driven.

With bookmark folders driven to the left-hand bar, there's more vertical space in Arc—you don't even get the familiar File or Edit menus, and just small forward, back, and refresh buttons, so there's often more of a web page on the screen at once, while tiling two side by side makes text-based pages easier to read.

Elsewhere, there are built-in mini-apps, Note and Easel, which in the case of the former, simply let you write things and share them, while Easel is a digital whiteboard through which you can collaborate with others, embedding videos and even whole web pages into your creations.

CHROME

Old favorite Chrome has 65 percent of the desktop browser market, and comes backed by a web store that hosts over 123,000 extensions and another 30,000 themes. It may be a traditional browser that can trace its UI back to the beginning of Internet Explorer and beyond, but it's highly customizable and runs extremely smoothly. The way it works with Google services such as Gmail and Drive is a boon for those who like to work in the web apps.

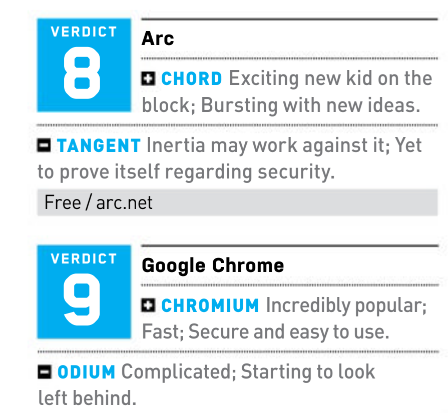
Chrome's reputation as a RAM hog is fading, as Google added a memory saver option back in 2023 that puts tabs to sleep when they're not being used—hovering your pointer over the inactive tab tells you how much has been saved. Edge does a similar thing, but you'll still see memory gobbled up in all browsers if you have lots of resource-hungry tabs open.

Despite strong competition from Microsoft and Mozilla, Chrome remains one of the best general-purpose browsers. It's secure, with a built-in password manager that will suggest strong passwords and remember them for you, syncing them across all the devices you're signed into with your Google account. It has other tricks, too, such as advising you if your passwords are likely to have been compromised in a data breach, the reader mode that strips a page of distractions so you can concentrate on the text, or tab management features that allow you to pin, close, reopen and remember whole windows' worth that can be reopened from the History listing after you've closed them.

What it lacks are features such as Arc's sidebar or Edge's vertical tab layout—Chrome keeps things very traditional, with the tabs and address bar at the top—but for those who like to keep a lot open at once, there's a drop-down menu that lists your tabs and allows you to search them.

Chrome remains the most popular browser thanks to its ease of use and reputation for speed and security, and the fact it's the de facto browser on a lot of mobile devices probably doesn't hurt, either. Despite Microsoft baking begging messages into Windows to try out Edge, Chrome is one of the first things many new PC owners install.

Switching browsers is a bit like moving house—you sometimes have to do it, but you'd rather not, and it can take a lot of time and effort, so it's no wonder many users stay with Chrome or Edge. Trying something new, however, costs you nothing, and with Arc, we may have seen a little glimpse of the future of web browsing. –IAN EVENDEN



VERDICT **8** **Arc**

CHORD Exciting new kid on the block; Bursting with new ideas.

TANGENT Inertia may work against it; Yet to prove itself regarding security.

Free / arc.net

VERDICT **9** **Google Chrome**

CHROMIUM Incredibly popular; Fast; Secure and easy to use.

ODIUM Complicated; Starting to look left behind.

Free / google.com/chrome

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Budget gaming
> Stealthy office builds
> Modern benchmarking

Gaming for $1,000

I really enjoyed your $800 Gaming PC cover feature in the June 2024 issue. While I wasn't surprised to see that a PC without a GPU wasn't great for playing games, it did get me thinking about what I might be able to build myself on the budget end of things. I'm about to start my first year of college, and I think I can just about convince my parents to give me the money to build a PC if I can keep it under $1,000! What can I reasonably expect in terms of gaming performance for that money, and what are the key components I should be looking at? **–B. Duggan**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks for the feedback on last issue's cover build—while we are 'Maximum PC', we do try to keep things balanced with a few value builds per year. When AMD's 8600G CPU arrived promising basic gaming performance without the need for a GPU, we were intrigued, to say the least. However, as you remark, its real-world gaming frame rates were passable at best in the major titles we use for benchmarking. It really shouldn't be thought of as a GPU replacement—rather something you can use to play casual or eSports titles now and again, if for some reason you can't have a dedicated graphics card in your system.

The good news is that it's very possible to meet your request and build a gaming PC on a $1,000 budget. This would also be a system capable of running modern titles at playable frame rates—even graphically intensive ones like *Cyberpunk 2077*. You can obviously look at the alternative builds Zak featured in last month's cover feature, as well as the blueprints he compiles at the back of each issue. The key component for you to look at is obviously the GPU. Zak recommends you look at an Intel Arc A750 ($200), AMD RX 7600 ($260), or RX 7600XT ($330) at this budget, and just this week, I've seen the RTX 4060 Ti hit around the $300 mark, so I would add that to your list.

From there, I'd suggest looking at the components from his cover build last issue, particularly the Phanteks XT Pro case ($50). I have a slight preference for Intel CPUs at the moment, given how cheaply you could then pair it with a Z690 or Z790 motherboard—the Intel Core i5-14400F is $200, a mobo the same price or less, plus you can choose between DDR4 or DDR5 memory. Get a decent air cooler (no more than $50), power supply like the models Zak suggests ($60), and SSD storage ($70-100, depending on capacity) and you should just about come under that $1,000 sweet spot.

The caveat here is that with these components, you shouldn't expect to be gaming at 4K—I'd suggest either a 1080p or 1440p monitor, but the good news is that there are plenty of decent screens that don't break the bank. Again, the Nvidia GPU option might help you here thanks to its upscaling tech. And of course, don't forget to budget in a keyboard, mouse, and maybe even a gamepad, too.

If you want more discussion of the current state of the budget market, be sure to watch Zak and I discuss it in our 'Story of the Build' video, a link to which you can find on page 17 of last issue.

Oh, and good luck in your studies!

Dark future

I don't know about you, but I've gotten weary of the whole RGB thing. It's actually quite difficult to find case fans that possess both good cooling performance and good lighting performance.

I wonder what you think of the idea of doing a compact ATX workstation build (not HTPC build, but mini ATX for ease of build and maintenance) that is high-powered for standard needs, but is dark, and maybe even skips the tempered glass for a closed side panel, going old school? I've been thinking that this may well be my next build if I don't go with a laptop and docking station. **–R. Matlow**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks for another build request—I always love hearing what sort of

↘ submit your questions to: editor@maximumpc.com

machines you want to see us turn our hand to next.

I'm slightly confused by the first paragraph in your email—it sounds like the fans you're buying at the moment are indeed RGB, but neither the lighting nor performance are up to scratch. From personal experience, the fans I've used from NZXT and Corsair have offered both good airflow and lighting, although they're not cheap.

On the other hand, if you want great fans, but without the lighting, I'd personally be looking at those from Noctua. They're famous for their brown-colored products, but you can get nearly everything in their chromax black colorway, if you prefer a stealthier look.

In terms of the compact ATX workstation, I think this is a great theme for an upcoming build. I also think a compact size is a good idea, as if it's for an office, no one wants something that's going to completely take over what might be a small amount of space. I love NZXT's H1 case (which I built in for the August 2022 cover feature), but I suspect that's maybe a little small—I found it quite fiddly, so it might not tick your boxes there, although it did have a large 3070Ti GPU in there.

NZXT's H5 Flow might be a better choice, as it's a compact mid-tower that comes with a quiet non-RGB fan, and is available in black, as you've specified. It's also pretty good value at $95.

Of all your requests, the most difficult is the case that doesn't feature a tempered glass panel! You're definitely going against the current fashion in PC case design there. I'd suggest looking at the Fractal North case, which can be specified with a mesh panel instead, or the Corsair 2000D Airflow Mini-ITX, although the latter might be too small for your needs. If you find anything suitable, be sure to let us know!

Make my PC sweat

I recently received a bonus at work, and decided to spend it on that high-end gaming PC I've always wanted. It boasts an Intel Core i9-14900K and an Nvidia RTX 4090, so it's as advanced as it gets right now.

However, I've been out of the PC gaming world for a few years, and I'm interested in what titles the *Maximum PC* team uses to push their machines hard. Of course, I see the games you use for benchmarking, like *Cyberpunk 2077*, *Metro Exodus*, and *Total War: Warhammer III*, but they're all a couple of years old now!

Basically, what can I use from the last year or so to make my system sweat and my console-owning friends green with envy?

–S. Baxter



© FRACTAL

Non-glass side panels are hard to find, but the Fractal North comes with a mesh option.

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: You make a fair point about our benchmark titles. It was our July 2022 issue, when we built three PCs at three different budgets, that we last took the opportunity to overhaul our benchmarking software.

The truth is, though, that most of those games would remain the same even today. It feels to me like a truly revolutionary PC game only comes around once every few years or so. I'm sure many of you remember how long the original *Crysis* remained the leading benchmark for PC gamers, with the question of, "Can it run *Crysis*?" remaining relevant for years after its release.

To me, *Cyberpunk 2077* feels like the current generation's equivalent—it's graphically intensive, has an incredible visual style, and thanks to all the post-release support that developer CD Projekt Red has put into it, it's a really enjoyable game to play as well.

I think the game that's been released since we last updated our test suite that we'd definitely add to the list today is *Alan Wake 2*. It fulfils all the same criteria I listed for *Cyberpunk* above, but it also has the most absurd system requirements if you want to run it at 4K with high settings and ray tracing. You'll need an RTX 4080 or higher, and even then, you'll need to enable DLSS to keep things running smoothly. The resulting visual spectacle is a joy to behold, however, and is probably the best justification for splashing the cash on a high-end PC as you've done.

I also recently played *Senua's Saga: Hellblade 2* on my personal RTX 4090, and as our sister title *PC Gamer* noted, it's visually spectacular—the closest I've seen a playable game come to recreating those amazing Unreal Engine 5 tech demos that have been around for a few years now. Sadly, as *PC Gamer* also notes, as good as the visuals are, it's narratively limp. Still, it's a short game, and you can play it on Xbox Game Pass if you don't want to pay full price.

Dragon's Dogma 2 has also become a popular title for PC users wanting to benchmark their systems, although I've not played it personally. It got a positive review in our May 2024 issue though, so it's worth playing!

Other than that, my two personal favorites are *Red Dead Redemption 2* and *Metro Exodus Enhanced Edition*. They're not the brand new titles you requested, but they both look spectacular. *Red Dead* features the most beautiful open world I've ever experienced, and *Metro* comes with all the Nvidia ray tracing and DLSS features you want to try when you get a new GPU. Enjoy!

THE BUILDS

THIS MONTH'S STREET PRICES...



WE'RE BEING very aggressive with our budget builds this issue. There have been a number of tweaks and changes to really try and make the most out of the budget we have, and see if we can't drop the price to sub-$900 without compromising too heavily on performance while we do it.

Our AMD build had a few subtle changes in price, with last month's spec dropping by $2. Still, we've swapped the motherboard for the ASRock B650 PG Lightning to save even more. It's still a full-fat ATX board, with suitable power solutions, plenty of connectivity, and decent memory support, too.

Also, after seeing how aggressively prices have fallen on the DDR front, we've upgraded to a 32GB kit of DDR5 as our minimum budget spec moving forward. Admittedly, 5600 C46 isn't the best spec out there, but it's $12 extra for double the capacity. The final tweak comes in the form of our secondary 1TB PCIe SSD, where we've gone for the Crucial P3 SSD, as it's slightly cheaper (by $4) than the MSI Spatium from last issue.

You might also be tempted by AMD's latest 8400F chip. Six cores, 12 threads, no iGPU, and a full PCIe complement sounds tempting, but clock speeds are lower, and the cache has been halved compared to the 7600.

As for Intel, the memory bump pushed our price up by around $20, and the RX 7600 is still more costly than the A750, so we've dropped down to the cheapest B760 board we could find. PCIe support is solid (with 4.0 as standard), but you only get two DDR5 slots, and I/O is a bit slim, so you might need a USB hub.

You could also swap the 14400F for something like the 12400F for a $76 saving, or even grab a 12600K for $175 instead. Of course, the biggest saving would be to swap out the chassis for something like Phanteks' XT Pro (reviewed on page 87), which would save you another $45 on each of these builds.

AMD INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	600W Thermaltake Toughpower GX2 80+ Gold	$60
Mobo	ASRock B650 PG Lightning ATX AM5 **NEW**	$150
CPU	AMD Ryzen 5 7600	$189
GPU	ASRock Challenger D Arc A750 8GB	$200
RAM	32GB (2x16GB) TeamGroup T-Create Classic @ 5600 C46 **NEW**	$84
SSD 1	512GB ADATA Legend 840 PCIe 4.0 M.2	$45
SSD 2	1TB Crucial P3 PCIe 3.0 M.2 **NEW**	$61
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$916**

INTEL INGREDIENTS

PART		PRICE
Case	Corsair 4000D Airflow	$95
PSU	600W Thermaltake Toughpower GX2 80+ Gold	$60
Mobo	ASRock B760M-HDV/M.2 Micro-ATX **NEW**	$95
CPU	Intel Core i5-14400F **NEW**	$200
GPU	ASRock Challenger OC RX 7600 8GB	$260
RAM	32GB (2x16GB) Silicon Power DDR5 @ 5600 C46 **NEW**	$76
SSD 1	512GB ADATA Legend 840 PCIe 4.0 M.2	$45
SSD 2	1TB Crucial P3 PCIe 3.0 M.2 **NEW**	$61
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$924**







BOUNCING PRICES are wreaking havoc with our mid-range builds. Just take a look at our AMD build, with the componentry we had last issue. The GPU went up by $40, the RAM by $35, and the SSD by $10. The price drops were $3-5 at most. That's frustrating, which is why we've gone aggressive on the parts swap this time.

For our AMD rig, we've swapped to a new GPU, the best-value RX 7800 XT we could get in the form of the Asus Dual OC. That alone shaves $20 off last month's price.

We couldn't skimp on memory, particularly as our requirements for the mid-range are a minimum of 6,000 MT/s and a decent CAS latency. Still, for only $15 extra, we managed to hit that frequency and tighten up the CAS to C30, versus last month's 34 (it's still $20 cheaper than the Vengeance kit). Lastly, our SSDs also got a revamp, swapping out to the Lexar NM790 (which you can read about more on page 76), and the Patriot P400 Lite as our back-up 2TB drive. The heatsink variant for the NM790 is cheaper than the non-heatsink version, so grab it while you can. All that has helped us shave $36 off the AMD build.

Our Intel build has also been hit hard. We didn't feel that it was right to have the same CPU in both budget and mid-range builds, so have gone for the 14600K with its higher clocks and more cores. That bumps up the price by $95, so to offset that we've dropped the motherboard down to the Z790-S, and switched out the GPU to a PNY Verto edition, saving $35 here. The build is $46 more than last month's, but that's only $5 a thread, and you get tighter memory timings.

Right now, that H7 Flow is incredible value, and a bit of a beauty for a build like this. There are a number of cheaper options, but you give up a bit of build quality, so we'll stick with the H7, although the Hyte Y40 is also a nice alternative if you're looking for something a little more bespoke.

AMD INGREDIENTS

PART			PRICE
Case	NZXT H7 Flow		$97
PSU	850W Thermaltake Toughpower GF1 2024 80+ Gold		$95
Mobo	Gigabyte X670 Gaming X AX V2 - AM5		$205
CPU	AMD Ryzen 7 7700		$277
Cooler	Noctua NH-D12L Chromax.Black	NEW	$100
GPU	Asus Dual OC Radeon RX 7800 XT	NEW	$460
RAM	32GB (2x16GB) Silicon Power Xpower Zenith Gaming @ 6000 C30	NEW	$95
SSD 1	1TB Lexar NM790 w/Heatsink M.2 PCIe 4.0 SSD	NEW	$85
SSD 2	2TB Patriot P400 Lite M.2 PCIe 4.0 SSD	NEW	$105
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)		$32
Approximate Price:			**$1,551**

INTEL INGREDIENTS

PART			PRICE
Case	NZXT H7 Flow		$97
PSU	850W Thermaltake Toughpower GF1 2024 80+ Gold		$95
Mobo	MSI Z790-S Wifi ATX	NEW	$170
CPU	Intel Core i5-14600K	NEW	$306
Cooler	Enermax Liqmax III 360 ARGB		$80
GPU	ZPNY Verto OC RTX 4070 Super	NEW	$565
RAM	32GB (2x16GB) Silicon Power Xpower Zenith Gaming @ 6000 C30	NEW	$95
SSD 1	1TB Lexar NM790 w/Heatsink M.2 PCIe 4.0 SSD	NEW	$85
SSD 2	2TB Patriot P400 Lite M.2 PCIe 4.0 SSD	NEW	$105
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)		$32
Approximate Price:			**$1,630**



IT'S SO CRAZY how different the marketplaces are depending on your budget. If you take a look at our mid-range and entry-level builds, it's so aggressively priced, and there are these huge pricing swings—it's hard to keep up. Yet, if you have $3,000, there's a constant deluge of deals, savings, and price drops. There's depreciation occurring on all the hardware.

Take our AMD build in this issue. The CPU received a $50 price drop, and the GPU we swapped out to the same model of graphics card from a different partner (complete with insane cooling and RGB), saving $130. Then there's the Intel build, where we changed very little. The SSD was $10 cheaper, the CPU $20, the GPU $30, and the cooler fell by $10. It was a constant stream of deals and offers that added up to some big savings. For instance, our AMD build, with an identical spec, dropped in price compared to last issue by $179. Our Intel build, even with one slight tweak to the PSU and SSD, dropped by $90. That's close to 10 percent of the budget we have for the entry-level builds.

The biggest shuffle came in the form of the power supply, as that had a price increase of around $30 (pretty much every 1200W PSU and above seems to be at the $180 mark), so we switched that for its 1000W cousin instead. You still get that 80+ Platinum efficiency rating, and it's still enough for both builds, with the AMD build topping out at around 685W and the Intel hitting around 720W, so you'll be more than comfortable.

There is one caveat—as we write this, Computex is occurring, and there are rumors of Nvidia launching a new barrage of GPUs, and AMD with a set of 9000 series CPUs. If the former does decide to leverage the might of the 12VHPWR600 connector, we could finally see 5000 series cards with a 600W TDP. That would boost power requirements if you do want to upgrade in future.

On that note, you may be better off holding fire for a moment. If the big three do launch new platforms and processors, we'll see a deluge of performance boosts, and older part deals land with us around September or just before it, which will be an ideal time for any budding system builder looking to revamp their rig.

AMD INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150
PSU	Super Flower Leadex Platinum SE 1000W - 80+ Platinum **NEW**	$140
Mobo	Asus Prime X670E Pro WiFi - AM5	$300
CPU	AMD Ryzen 9 7950X	$500
Cooler	Asus ROG Ryuo III 360 ARGB 360mm AIO	$190
GPU	ASRock Phantom Gaming OC Radeon RX 7900 XTX 24GB **NEW**	$900
RAM	64GB (2x32GB) TeamGroup T-Create Expert @ 6000 C34	$185
SSD 1	2TB Crucial T700 PCIe 5.0 M.2 **NEW**	$240
SSD 2	2TB Crucial T500 PCIe 4.0 M.2	$139
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$2,776**

INTEL INGREDIENTS

PART		PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$150
PSU	Super Flower Leadex Platinum SE 1000W - 80+ Platinum **NEW**	$140
Mobo	Gigabyte Z790 Aorus Elite AX-W ATX	$366
CPU	Intel Core i9-14900KF	$512
Cooler	Phanteks Glacier One 360D30 360mm AIO	$170
GPU	PNY Verto Overclocked RTX 4080 Super 16GB	$970
RAM	48GB (2x 24GB) G.Skill Ripjaws DDR5 @ 6400 CL36	$150
SSD 1	2TB Crucial T700 PCIe 5.0 M.2 **NEW**	$240
SSD 2	2TB Crucial T500 PCIe 4.0 M.2	$139
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32
Approximate Price:		**$2,869**

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